Survey of the Commercial
Soft-shell Clam (*Mya arenaria*)
Resource on the North Shore of
the Minas Basin, Bay of Fundy, 1982

by

Nancy B. Witherspoon

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Estuarine and Inland Fisheries
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Abstract

A soft-shell clam survey was conducted along the north shore of the Minas Basin during the summer of 1982. Acreages, densities, frequency distributions of all size classes, and abundances of market size clams (≥1 3/4" or 42-48 mm size class) were calculated. Shell samples were collected for aging purposes. Information on the past history and present status of the fishery were gathered.

Of the estimated 1,116 acres available for commercial clam digging, 354 were surveyed. Densities of the prerecruit 1 1/2" size class (36-41 mm) were high, with relatively small numbers of <3/4" size class (0-16 mm) and ≥2" size class (≥49-54 mm). Growth rates and asymptotic lengths are low compared to other areas in the Maritimes and along the Atlantic seaboard. Occurrences of stunting are common. Abundances of commercial size clams are considered moderate and exploitation rates are not extremely high. At the time of the survey, an estimated 67,114 bushels of market size clams, worth 1.3 million dollars, were available for harvest.

Concerns for the long term viability of this valuable and fragile resource are expressed. Management recommendations are presented.

1. Introduction

The Nova Scotian soft-shell clam industry is largely unrecognized. In 1981, 1.5 million dollars worth of clams were landed by commercial fishermen. This value is considered an underestimate, as significant quantities are sold privately and dug recreationally. Nevertheless, this figure exceeded the landed value of each of such high profile species as squid, gaspereau, salmon, mackerel, and queen crab in the province during the same year.

Since the early 1970's, landings in the Minas Basin clam fishery have increased. Now they represent approximately 30% of the total Nova Scotia fishery by weight (Figure 1). The value in 1981 was approximated at 0.5 million dollars, greater than each of the first three provincial fisheries previously mentioned.

The clam industry in the Minas Basin began with the purchase of the old ship block factory by Willard and John Coffil around 1905 (The Women's Institute, 1969). Located along the North River in the community of Five Islands, it became primarily important for canning clams, although some were purchased and sold fresh locally. Initially, few (less than six) diggers were employed. Workers preferred forest, fishing, farming, and tourist industries, where jobs were abundant and better paid.

Some time before 1910 the clam factory burnt down. It was rebuilt nearby on Broderick's Beach. Shortly afterward, Dr. Archibald Davidson bought and named it the Evangeline Clam Factory. Perley and Allan Davidson, his nephews, ran the factory for him and later he sold it to them. The business changed hands once more in 1915. The new owner, Isaac Fulmer, bought clams for $1.00 a barrel (2 1/2 - 3 bushels). A day's catch was hauled in from the flats by dory at high tide, cleaned, cooked and canned. The majority of the product was shipped to United States markets.

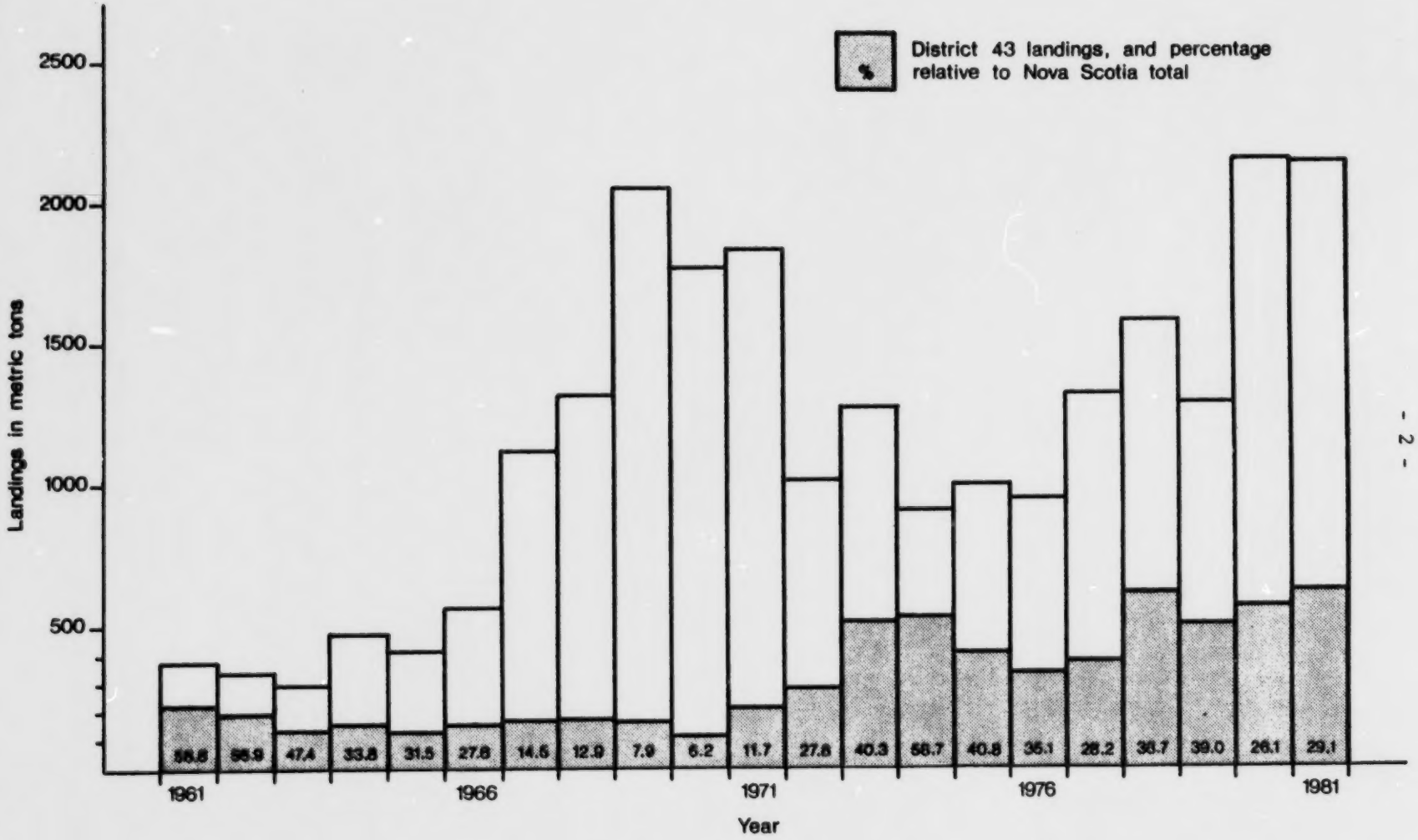

Figure 1. Landings of soft-shell clams on the north shore of the Minas Basin (District 43) and percentage relative to the total for Nova Scotia, 1961-1981 (from Fisheries and Oceans Statistics).

Except for a temporary exchange of ownership with a Mr. Pridham around 1918, the clam business under Fulmer remained relatively unchanged up until the 1940's.

By 1941 there was commercial digging in Parrsboro Harbour in addition to the Five Islands area. The next year Aurele LeBlanc, from the north shore of New Brunswick, purchased and expanded the canning plant (ibid.).

Between 1938 and 1943 the price for clams rose from 33 to 85 cents per bushel. The numbers of diggers climbed to one hundred and the landings increased dramatically (Figure 2). The overnight boom in the clam industry was sparked by greater demand for the product and restricted fishing in the Minas Basin due to airforce bombing and gunning practices (Medcof, 1949).

The factory produced canned clams under the "Bay of Fundy Brand" label (Figure 3). It employed approximately fifty people. Initially, both diggers and factory workers were brought in from New Brunswick, but later, more local people participated.

The only fishery regulation at that time was a 2 1/4" (57 mm) size limit which also applied to the other commercial clam fisheries in Nova Scotia. The provincial Department of Fisheries was concerned about the lack of market size clams on the flats. They asked federal government officials to investigate this problem. Scientists from St. Andrews Research Station found large proportions of stunted, slow growing, and old clams less than legal size on the commercially dug flats (ibid.). They concluded that many clams would die before ever reaching the size limit and recommended that it either be reduced to 1 3/4" (45 mm) or be abolished entirely. On May 12, 1944 the size limit was revoked. In practice very few clams were harvested below 2" (51 mm) because larger clams were more economical to shell (i.e. more meat weight per unit of effort).

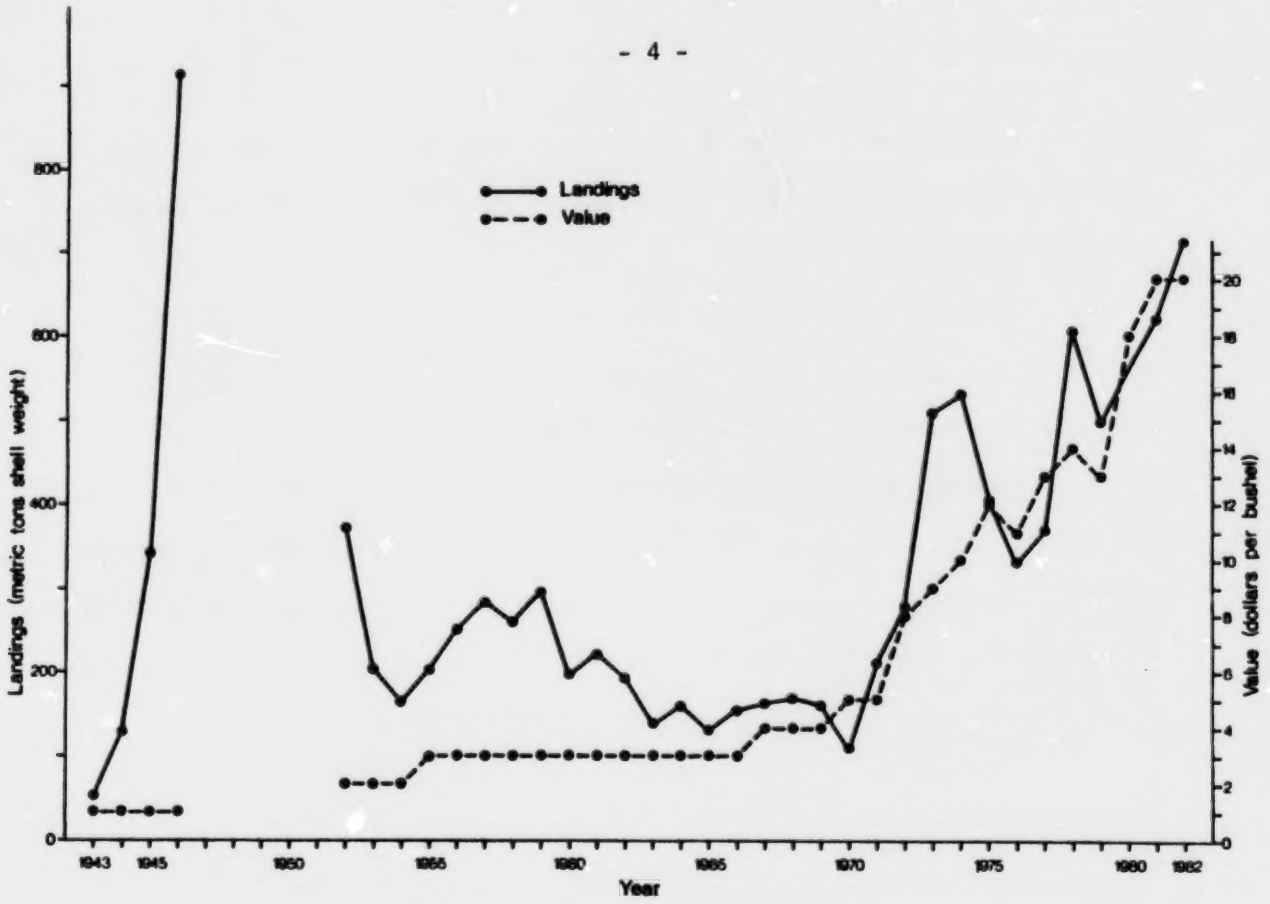

Figure 2. Landings and bushel values of the soft-shell clam from 1943-1982 for the north shore of the Minas Basin (from Fisheries and Oceans Statistics).

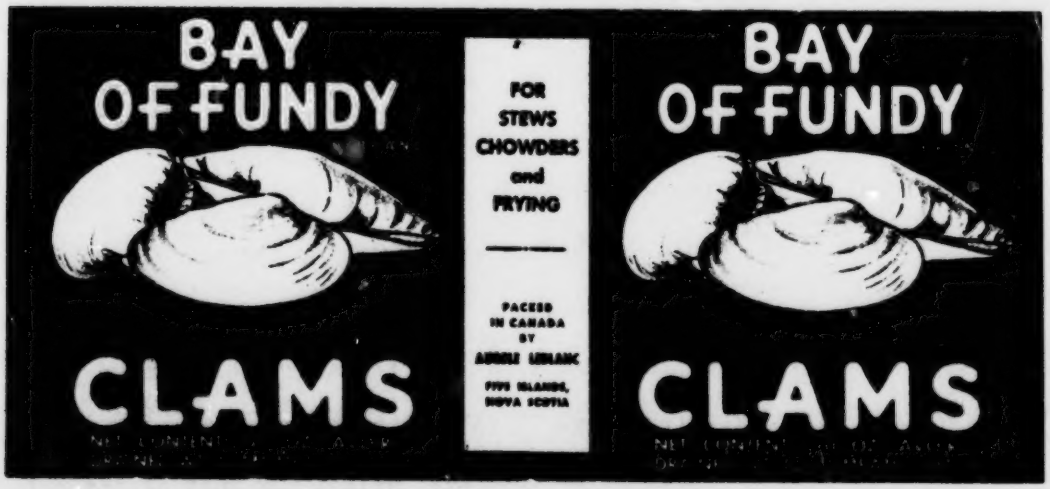

Figure 3. Label for canned clam product from Five Islands factory during the 1940's.

Clam digging expanded to the Economy area and from 1946-1947 a clam factory, which later burned down, operated at Carrs Brook. It was during this period that the largest landings, up until that time, were recorded (Figure 2). Catch per unit effort (CPUE) statistics (bushels per person per tide) were high. For a five hour tide, an average catch was 8 bushels. Occasionally 14 bushels were taken in a productive area and for a long tide.

After 1947, and up to the 1960's, landings declined as did the numbers of fishermen. From an average of 100 clam diggers per year during the 1940's, the numbers dropped to figures ranging between 20 and 70 a year for the following two decades. Prices continued to remain relatively stable. The two dollar value of a bushel of clams in 1951 had only risen to three dollars by 1956. Low price coupled with CPUE's reduced to 3-4 bushels per tide were indicative of a less prosperous fishery. Fishermen were even forced to venture further afield to places such as Advocate Harbour in order to make a living.

On December 24, 1960 LeBlanc's factory burned down (The Women's Institute, 1969). It was rebuilt in 1961 a little closer to the main highway. A Mr. Murcheson purchased the factory in 1967 and resold it a year later to D.A. Casey. It changed hands a few more times, Casey selling to a Mr. Massey who in turn sold it to Peter Marcus. The factory, under Marcus' ownership, was again destroyed by fire sometime in 1969-70.

The 1960's saw some changes in the industry which improved the economic climate in subsequent years. The law prohibiting the shipment of clams in the shell outside of the province was abolished in 1967. That same year live clams were exported to the province of Quebec for Expo 67. By the end of the decade, the transition from a canned product to fresh shucked clams had emerged in response to the American deep fried trade. In addition, reduced effort in past years had given clam stock densities

time to recover.

About 1970, Coreen Goguen and Adrien LeBlanc started buying clams chiefly for sale to New Brunswick. A year later Oswald Cormier built and opened a new clam factory on the road to Sand Point, closer to central Five Islands. Prices increased rapidly as markets grew, and numbers of diggers and landings again were on the rise. CPUE's averaging 4 - 5 bushels per tide reflected somewhat improved abundances.

Licensing of commercial clam diggers was required by the federal government from 1978. Parrsboro Harbour and the mouths of East and Harrington Rivers, in Five Islands, were closed to commercial fishing by 1979 because of faecal bacterial pollution.

Market-size clams ($\geq$1 3/4", $\geq$42-48 mm size class)[1] have been shucked in Five Islands for both local, Maritime, and U.S. consumption since the 1970's. The remainder is shipped to New Brunswick for processing or further distribution. Larger proportions of small clams (1 1/2 - 1 3/4", 36-48 mm size classes), called steamers, have been dug for live sale to U.S. markets from 1980 to the present.

For 1982, a peak of 710 MT of clams worth over 0.5 million dollars has been reported for the Minas Basin, District 43. The same year, one hundred and ten full time commercial fishermen plus numerous part-timers and students were engaged in digging clams. There were three processors in the area with a hired staff of twenty-seven people to process the harvest.

The industry is largely unmechanized and therefore requires low capital investment, since most of the digging and processing is done by hand.

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[1]Size classes were chosen to place clams in metric length groupings represented by a single Imperial measure. For example, the metric range of the 1 3/4" size class is 42 to 48 mm (see Tables for breakdown). In other instances the actual metric equivalent is used, e.g. 1 3/4" = 45 mm. Measurements other than clam lengths are metric.

CPUE's averaged 2 1/2 - 3 bushels per person for a four hour tide in 1982. Reduced abundances have again induced fishermen in the past two years to travel west to Advocate Harbour to augment their catches.

Historically, the Minas Basin clam fishery has fluctuated in prosperity relative to clam abundances, market demand, increased effort, and subsequently landings. The market size clam has mainly been above 1 3/4" (42-48 mm size class) for economic reasons. The absence of a size limit and the relaxation of export regulations have made possible the recent exploitation of smaller clams.

Besides management problems in the fishery, there are threatening environmental issues. A proposed tidal power barrage from Economy Point to Cape Tenny (B in Figure 4) could have an impact on the resource. Furthermore, continued problems with bacterial pollution are likely, unless sanitary practices in the area are improved.

Concern for future viability of the clam fishery on the north shore of the Minas Basin has prompted this investigation by the Nova Scotia Department of Fisheries during the summer of 1982.

2. Methods

2.1 Field Procedures

Pre-survey work involved the identification of 17 clam flats of commercial importance. Fishermen and processors provided information on past and present commercial productivity of these flats, so that a priority list could be constructed. The five flats considered most important were chosen for detailed survey work, and included: Sadies, Carrs Brook, Harrington Beach, The Tower and Little Bass River (Figures 5, 6, and 7). Fortuitously, these flats represented the most easterly and westerly sections of the major commercially exploited area along the North Shore of

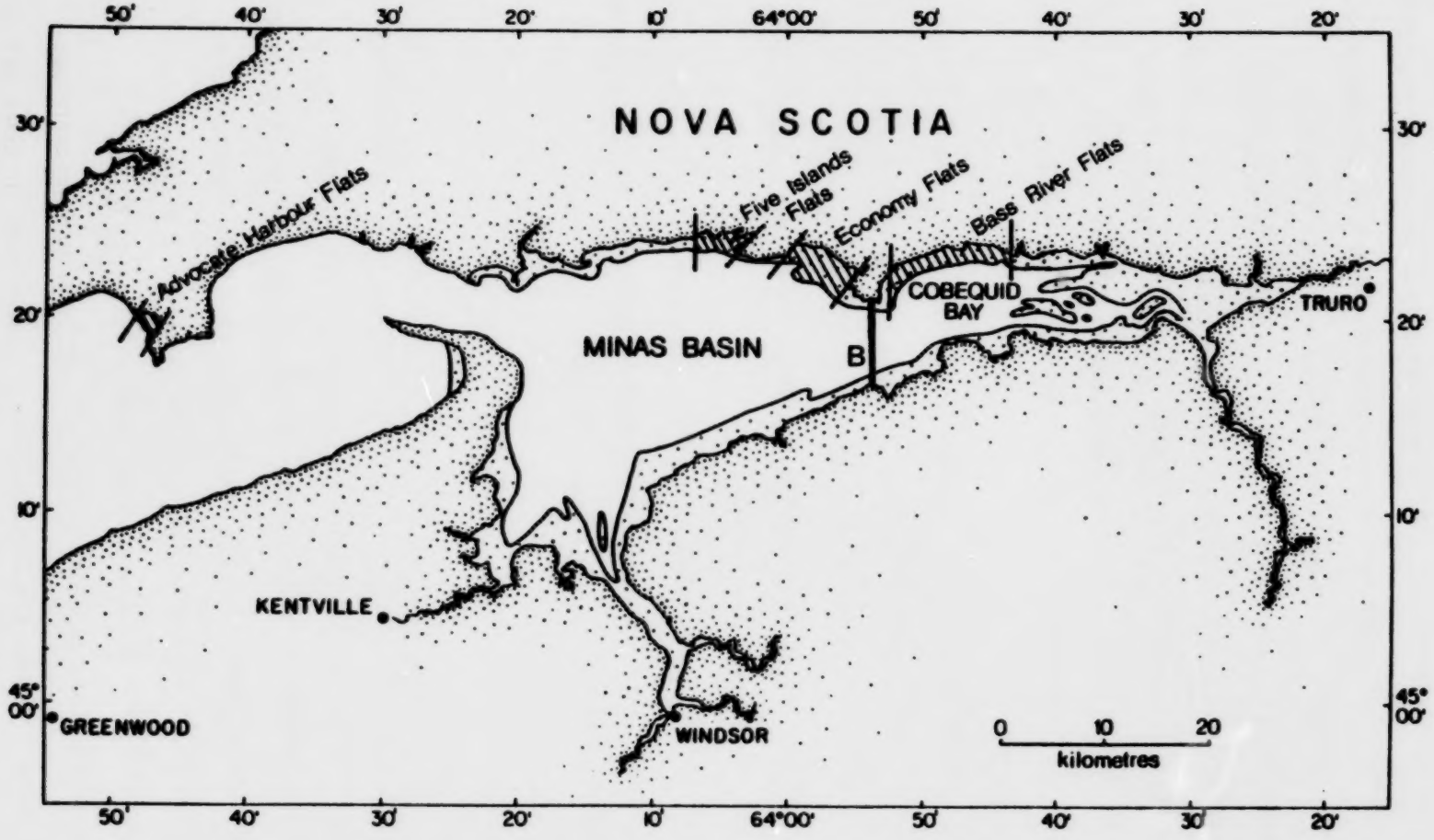

Figure 4. Location of soft-shell clam flats on the north shore of the Minas Basin (modified from: Geomorphology and sedimentology of the Bay of Fundy, Trip 23 of the Geological Association of Canada and the Mineralogical Association of Canada, May 1980, authors C.L. Amos et al.). The proposed position of the tidal power barrage is indicated by the letter "B".

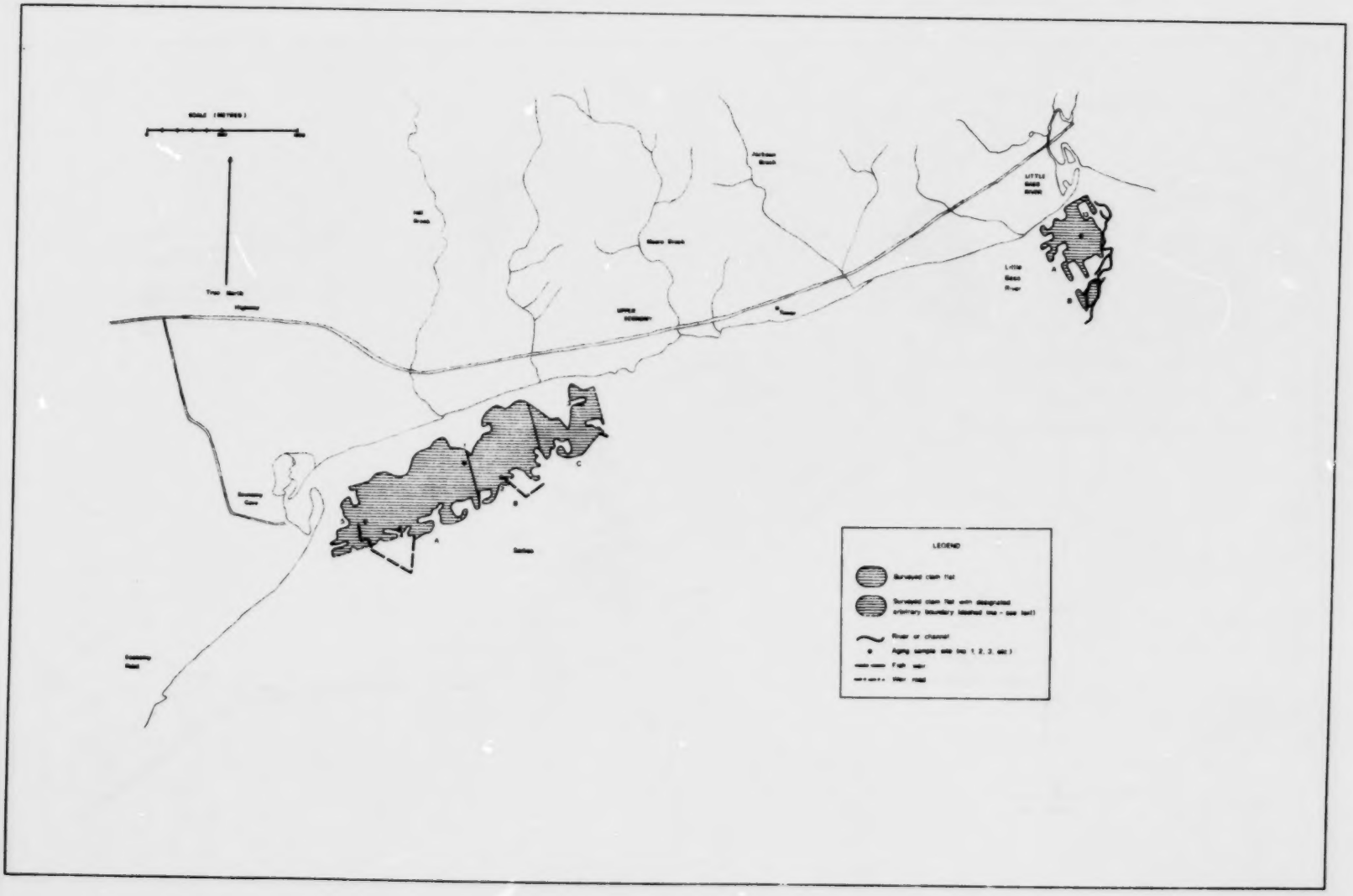

Figure 5. Locations and configurations of the surveyed Bass River clam flats and positions of aging sample sites, 1982.

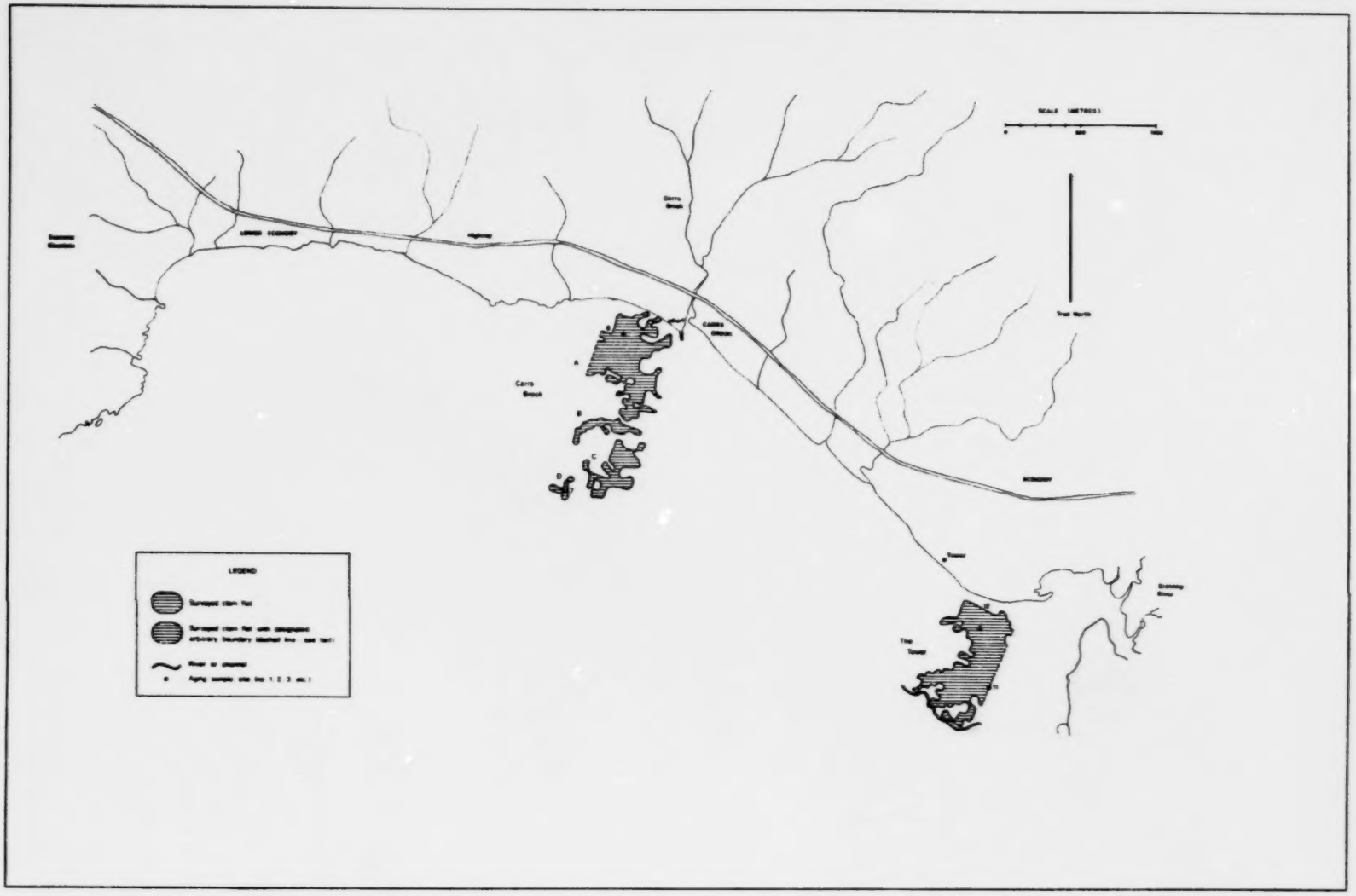

Figure 6. Locations and configurations of the surveyed Economy clam flats and positions of aging sample sites, 1982.

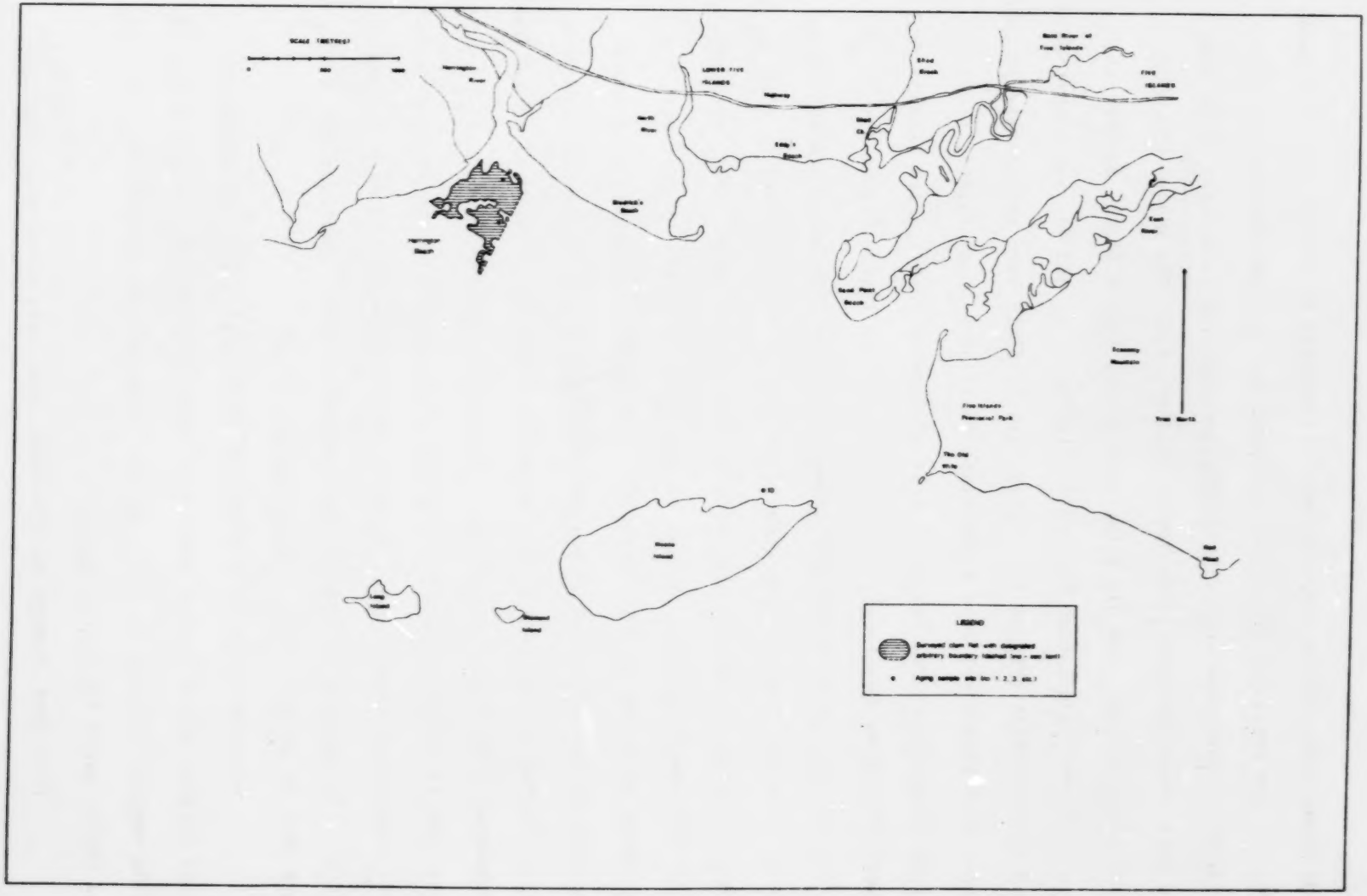

Figure 7. Locations and configurations of the surveyed Five Islands clam flat and positions of aging sample sites, 1982.

the Minas Basin and in addition were distributed on either side of Economy Point. The remaining flats, not surveyed due to time constraints, were visited to determine approximate acreages and clam densities. From east to west these included: Five Houses, Saint's Rest, The Miller Place, Soley-town-Lower Economy, The Old Wife, Sand Point, Eddy's Beach, Broderick's Beach, Moose Island, Blue Sac Beach (Figures 5, 6, and 7), and Lubber Hole and Advocate Flat (Figure 8). Later, all 17 flats were arbitrarily grouped under four locations: Bass River flats (east of Economy Point), Economy flats (east of Economy Mountain, west of Economy Point), Five Islands flats (west of Economy Mountain), and Advocate Harbour flats (Figure 4).

The actual field work commenced on May 25th and ended September 20th. Transect line-quadrat techniques similar to those used in clam survey work conducted on the Eastern Shore in 1981 (Witherspoon, 1982) were employed, with some modifications. Access to most clam flats was by foot with the exception of Moose Island. Transect lines were consistently 30 m apart parallel to the shore and 50 m apart perpendicular to the shore. In most areas, except Little Bass River, surveying could have continued beyond the boundaries indicated (see arbitrary boundaries, Figures 5, 6, and 7). However, due to lack of time, the work was discontinued beyond areas considered most commercially important. Aluminum stakes were used to mark quadrat locations. The majority of samples were sorted by hand. Consequently, clams less than 20 mm are likely underestimated.

Fourteen sites on a number of commercial flats, at different tidal heights and in varied substrate types, were chosen for collection of aging samples (Figures 5, 6, 7, and 8). Samples were immediately processed and shells saved for future aging.

From June through to September, observations on meat condition were made.

Figure 8. Advocate Harbour clam flats and position of aging sample site, 1982.

While in the field and when time permitted, digger counts and random interviews were conducted. Commercial fishermen were asked questions about their catch, effort and other information related to the commercial fishery (Appendix 1). Recreational fishermen also responded to questions concerning the relative importance of clam digging to their holiday plans.

Clam landing data was obtained from Fisheries and Oceans, Statistics Division. Historical information on the fishery was collected through interviews with processors, diggers, fisheries officers, and residents of the Five Islands-Economy area.

2.2 Treatment of Samples

2.2.1 Map Work

Map and compass methods were identical to those used in the 1981 study (Witherspoon, 1982). Great distances of sighting points and rapidly eroding shorelines caused some difficulties in reconstruction of surveyed areas during map drawing.

2.2.2 Numerical Tabulation

2.2.2.1 Stock Assessment

Clams were grouped into size classes as in the 1981 study. Inspection of size frequency distributions indicated that clams were partially exploited from 1 3/4" (42-48 mm size class) and above. Two types of groupings of prerecruits and markets were used:

Type I	Type II
Juveniles $\leq$1 1/4" ($\leq$35 mm)	Juveniles $\leq$1 1/4" ($\leq$35 mm)
Prerecruits 1 1/2 - 1 3/4" (36-48 mm)	Prerecruits 1 1/2" (36-41 mm)
Markets $\geq$2" ($\geq$49 mm)	Markets $\geq$1 3/4" ($\geq$42 mm)

The type I grouping was included so that comparisons could be made with abunddances of clams in other areas of the Maritimes where 2" (51 mm) is the minimum legal harvest size. On the north shore of the Minas Basin, where there are no restrictions, clams 1 3/4" (42-48 mm size class) and above are taken.

Summaries of acreages, numbers of stations, and clams measured were prepared by location, flat, and areas within flats. Tables of size classes, densities in numbers of clams per ft^2 (0.09 m^2), bushels per acre, and total production (bushels) were completed.[2] Bushel calculations were done for only prerecruits and markets of both Types I and II. Conversions from numbers of clams per size class to bushels were completed using Table 1.

Graphical representations of size frequency distributions (numbers per ft^2 or 0.09 m^2) are given for each location where surveys were conducted, for all locations combined, and to illustrate differences from inshore to offshore intertidal areas.

For areas that were not surveyed, methods for calculating production in bushels were different and results less accurate than for those that were surveyed by transect line-quadrat method. Using map and compass, distance from the beginning of the clams in the upper part of the intertidal zone, to where they ended in the lower part, was paced on foot. At 90 m intervals along each pacing line, visual approximations of densities and sizes of clams were made from square foot hole counts and digs. In each area, pacing lines were spaced approximately 90-150 m apart along the shoreline and ended where absence of commercial digging or significant densities of clam holes were evident. With this information, areas were mapped and acreages calculated. Average densities per ft^2 (0.09 m^2) were approximated

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[2]Historically, inches, feet and bushels have been the traditional units of measure in the clam industries of both the Maritime and New England coasts. Today they are still used by processors and scientists to express size and volume measures.

Table 1. Number of soft-shell clams per bushel at selected sizes (from MacPhail & Medcof, 1955).

Size (length) mm	inches	Clams per bushel
36-41	1 1/2	2800
42-48	1 3/4	2200
49-54	2	1600
55-60	2 1/4	1180
61-67	2 1/2	920
68-73	2 3/4	700
≥74	≥3	560

Table 2. Statistical parameters of the log-log regression of shell width (mm) on shell length (mm) for soft shell clams in the Minas Basin, 1982.

log (shell length) = log α + βlog (shell width)

Site	Location	n	α	β	95% confidence limits α		β		r^2*
1	Sadies A - Midshore	187	.4905	.806	.4456	.5353	.773	.840	.961
2	Sadies B - Offshore	195	.5133	.926	.2814	.3453	.903	.950	.984
3	Sadies C - Inshore	201	.3266	.939	.2792	.3741	.905	.974	.967
4	Sadies A - Offshore	210	.3776	.899	.3369	.4184	.870	.929	.972
5	Sadies A - Inshore	204	.3117	.923	.2731	.3503	.894	.952	.975
6	Carrs Brook - Inshore	192	.3440	.927	.3011	.3868	.896	.957	.974
7	Carrs Brook - Offshore	209	.2670	.972	.2399	.2942	.952	.992	.989
8	Harrington Beach - Offshore	219	.2704	.965	.2378	.3030	.941	.989	.983
9	Harrington Beach - Inshore	202	.2975	.939	.2735	.3215	.922	.957	.991
10	Moose Island - Midshore	166	.3031	.949	.2551	.3511	.912	.985	.971
11	The Tower - Offshore	224	.2656	.969	.2281	.3030	.942	.997	.977
12	The Tower - Inshore	193	.3435	.919	.2804	.4067	.873	.964	.944
13	Little Bass River - Midshore	276	.2571	.973	.2091	.3052	.938	1.009	.956
14	Advocate Harbour - Offshore	229	.2821	.956	.2453	.3188	.930	.982	.979

*Correlation coefficient

for each area from the data collected. These results were compared to densities and size distributions of clams from previously surveyed areas. Bushel per acre figures for market size clams (≥1 3/4", ≥42-48 mm size class) were applied to unsurveyed areas which were considered similar in clam characteristics to surveyed areas, so that bushel production could be approximated. Tables summarizing acreages and bushels for market size clams are presented by unsurveyed areas and locations.

Grand total acreage and bushel production of clams greater than the 1 3/4" (42-48 mm) size class are given for both surveyed and non-surveyed areas and locations.

CPUE statistics were calculated for commercial fishermen on a monthly basis and for two clam flats where data was sufficient. Total 1982 CPUE's were summarized for both commercial and recreational fishermen.

2.2.2.2 Determination of Growth Rates

Methods for aging clams and analyzing the data were identical to those used in 1981 (Witherspoon, 1982). Young clams spawned in the summer months lay down their first growth ring the following winter. In older clams this ring becomes worn and is very difficult to read and therefore is ignored. Ring 2 is recorded as age 1 and is the first ring which represents a full year's growth.

Shell widths are converted to lengths and then run against age using the von Bertalanffy growth equation

$$L_t = L_\infty \left(1-e^{-k(t-t_o)}\right)$$

Theoretical values of the growth parameters L_∞ (length at which the growth rate is 0), k (rate of growth to L_∞), and t_o (age at which length is 0) were generated.

Statistical parameters of the allometric equation

$$\log (\text{shell length}) = \log \alpha + \beta \log (\text{shell width}),$$

used to convert clam widths to lengths, are presented in Table 2 for all fourteen aging sites. Tables 3 and 4 list the parameters of the von Bertalanffy growth equation, with confidence limits and standard errors, for each aging site. Fitted and measured lengths at age are given in Appendix 2. Plots of growth curves are used to illustrate the range of k and L_∞ values.

3. Results

3.1 Physical Setting

The main study area, encompassing approximately 40 km of coastline along the north shore of the Minas Basin from Five Islands to Bass River, is located 40 km west of Truro (Figure 9). Advocate Harbour, situated at the entrance to the Minas Channel, is about 65 km further west.

The former area is dominated by highly erodable sandstone cliffs, broken at intervals with rivers, bordered at their mouths by salt marshes. The clam flats themselves vary in width (measured shore to sea) from 500-1,000 metres. The more gradual the slope of the intertidal zone, the wider the clam flat and the longer the digging time. River and tidal drainage channels dissect the flats in various places. The substrate type varies markedly even over short distances and can range from soft oozy mud to sand and gravel. Sediments are fine near shore and progressively get coarser seawards. Substrate depth is also highly variable. Underlying hard pan clay or sandstone ledges can reduce depths to less than 10 cm.

Advocate Harbour is a sheltered sandy embayment, adjoined by marshgrass flats to the north. Brooks enter the harbour on the west and south sides (Figure 8). The embayment itself is characterized by large river and drainage channels and high gravel bars close to its seaward entrance. Clam

Table 3. Parameters for von Bertalanffy growth equations for soft-shell clams from the Minas Basin, 1982.

Site	Location	n	L_∞	k	t_o
1	Sadies A-Midshore	870	56.477	.154	-1.127
2	Sadies B-Offshore	791	56.067	.183	-.588
3	Sadies C-Inshore	1083	62.895	.156	-.455
4	Sadies A-Offshore	870	80.892	.138	-.273
5	Sadies A-Inshore	785	56.604	.171	-.440
6	Carrs Brook-Inshore	707	86.399	.154	-.123
7	Carrs Brook-Offshore	594	74.852	.201	+.001
8	Harrington Beach-Offshore	618	77.360	.160	-.408
9	Harrington Beach-Inshore	610	60.362	.220	-.177
10	Moose Island-Midshore	458	69.058	.191	-.202
11	The Tower-Offshore	691	59.986	.210	-.321
12	The Tower-Inshore	702	99.471	.109	-.331
13	Little Bass River-Midshore	1152	89.822	.097	-.255
14	Advocate Harbour-Offshore	1025	79.592	.127	-.392

Table 4. 95% confidence limits and standard error of estimates of parameters for von Bertalanffy growth equations from Table 3.

Site	Location	95% confidence limits						standard error		
		L_∞		k		t_o		L_∞	k	t_o
1	Sadies A-Midshore	54.124	58.830	.142	.167	-1.215	-1.038	1.201	.0064	.0451
2	Sadies B-Offshore	53.683	58.451	.168	.199	-.660	-.516	1.216	.0077	.0367
3	Sadies C-Inshore	61.379	64.410	.149	.164	-.497	-.413	.773	.0036	.0215
4	Sadies A-Offshore	78.481	83.303	.132	.145	-.304	-.242	1.230	.0033	.0159
5	Sadies A-Inshore	54.390	58.817	.159	.182	-.490	-.391	1.129	.0060	.0251
6	Carrs Brook-Inshore	83.766	89.033	.146	.161	-.155	-.092	1.344	.0039	.0161
7	Carrs Brook-Offshore	72.857	76.846	.191	.211	-.033	+.035	1.018	.0052	.0173
8	Harrington Beach-Offshore	73.958	80.762	.148	.171	-.453	-.363	1.736	.0060	.0231
9	Harrington Beach-Inshore	59.357	61.368	.212	.228	-.203	-.150	.513	.0039	.0136
10	Moose Island-Midshore	66.002	72.114	.177	.205	-.245	-.159	1.559	.0073	.0217
11	The Tower-Offshore	58.818	61.154	.202	.218	-.351	-.291	.596	.0041	.0152
12	The Tower-Inshore	89.047	109.896	.093	.124	-.379	-.283	5.319	.0078	.0245
13	Little Bass River-Midshore	85.693	93.952	.091	.103	-.282	-.228	2.107	.0031	.0137
14	Advocate Harbour-Offshore	77.814	81.370	.123	.132	-.418	-.366	.907	.0024	.0132

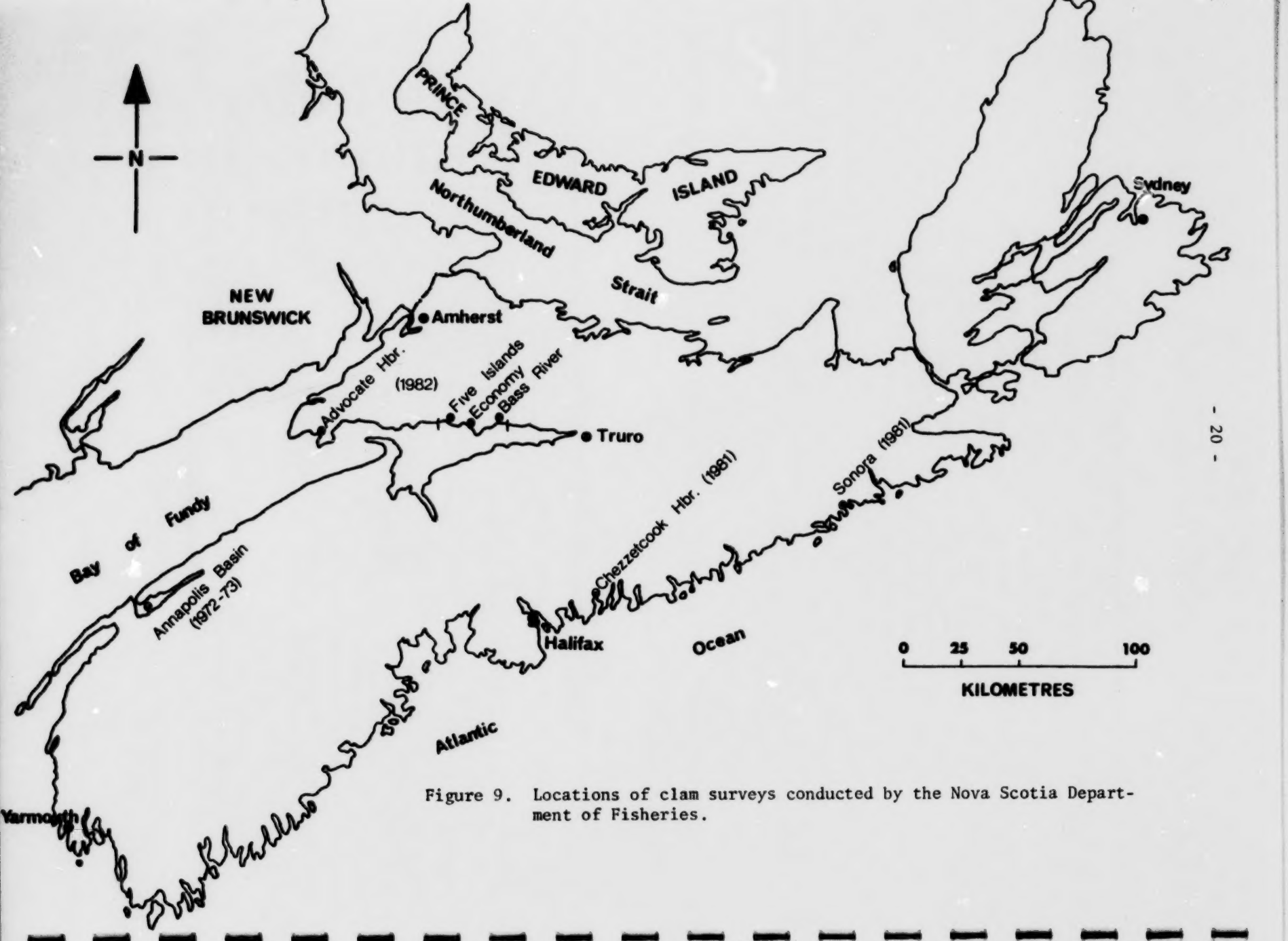

Figure 9. Locations of clam surveys conducted by the Nova Scotia Department of Fisheries.

flats are found between these channels primarily in the centre of the harbour.

Generally, flats of major commercial importance are found opposite mouths of rivers and in sheltered coves or in the lee of headlands. Distribution of clams is usually patchy and seems to be dependent on a variety of factors including sediment type and depth, height in the intertidal zone, and position relative to tidal and river drainage channels. Highest densities of clams are concentrated in well drained, medium grained, moderately deep (>10 cm) sediment types. A preference for the lower-middle to middle-upper part of the intertidal zone, and banks of tidal and river channels, was consistently observed. Commercial digging is most intense in these locations.

The Bay of Fundy is unique because it has the world's highest tides. In the Minas Basin, this incredible water movement, combined with westerly fetch storm-driven waves and winter ice conditions, result in an intertidal zone susceptible to dramatic erosional and depositional changes over very short periods of time. Yeo (1978) has aptly described this area as a high energy, low stability environment, where fast and efficient rates of carbon and nutrient transfer, from one trophic level to the next, produces a high density-low diversity assemblage of infaunal invertebrates with some of the highest biomass production values recorded in the literature.

3.1.1 Bass River Flats

3.1.1.1 Little Bass River

The most easterly area surveyed was divided into areas A and B due to an absence of clams in between the two areas (Figure 5). Although a relatively small flat, 513 m wide, it is actively dug every spring.

This flat is characterized by variable sediment types ranging from soft mud along the channel of the Little Bass River, which produces no clams, to mud-sand-gravel mixtures inshore, which have moderately dense quantities of clams. Areas of heavy gravel or rippled sand in the outwash

of the river offshore have no clams, while sediments to the west hold large white clams which are clumped in distribution.

Only one aging site (13, midshore) was selected. Clams, all about the same size (moderate), were taken from mud topped, sand-gravel bottomed sediments. The area had been commercially dug.

3.1.1.2 Sadies

A very large flat, Sadies (Figure 5) was arbitrarily broken into areas A, B, and C for ease of surveying. Widths of the three areas from the beginning of clams in the upper part of the intertidal zone toward low water were 433, 462, and 353 m, respectively. Approximately 120 m covered the distance from high water to the beginning of significant clam abundance.

Sediment type graded from fine grained mud-clays in the west (Sadies A), into mud-sand of the central section (Sadies B), to sand-gravel in the most easterly area (Sadies C). The river and associated salt marsh close to Sadies A seem to contribute the fine grained black muds which predominate in this area. Small brooks running through sandstone cliffs add coarse grained sands and gravels to the more easterly portions of the flat. Sandstone outcrops which occur as ledges in combination with hard pan clay bottoms produce shallow substrates (<10 cm) in portions of Sadies C.

Clams were concentrated in medium grained mud-sands of Sadies B and alongside intertidal waterways, common in Sadies A. Large numbers of dead shells were noted among them. Fine soft muds or heavy gravels yielded very few clams. Burrowing seemed to be deeper in sand than in mud. Fish weirs with numerous channels and coarser grained sediments had few clams. These observations commonly held true on most flats that were studied.

Juvenile clams (<3/4" size class, 0-16 mm) from the previous year's spawning were apparent in relatively high numbers in surface sediments of Sadies C.

This flat, compared to others in the area, has produced the greatest quantity of commercial clams in the last 2 years. In 1982 approximately 18% of the catch from the north shore of the Minas Basin was taken from Sadies.

Five samples of clams were collected for aging purposes. Site 1, located midshore and at the upper edge of commercial digging in area A, was characterized by a sand-gravel base and mud surface. Clams were very dense, thick shelled and small in size. Site 2, area B, was situated offshore in an area of commercial digging. Inhabiting predominantly sandy substrates, the clams were thin shelled and of a wide size range. Inshore, site 3, area C, was representative of shallow ledge, sand-gravel substrates. Clams were smaller and in lower densities here than the other two sites. Seaward from this site there was evidence of commercial digging. Positioned at the opening of the fish weir in area A, site 4 was occupied by moderately dense, black-shelled clams. The animals were larger and of a wide size range. The bottom was sand-gravel mixed with black mud which causes surface darkening of shells. Site 5, area A, was chosen as a location of very dense clams. Situated adjacent to a river channel, the clams were small, squat, and of approximately equal size. There was no commercial digging nearby.

Stunted clams, particularly prominent in most samples except site 4, were observed to be thick shelled. Jagged marks between annual growth rings were assumed to be shock marks indicative of disturbances, a result of intense digging practices on this flat. The animals here had highly variable ring 2 positions and differences in growth rates between rings within animals, and between animals within the same rings.

3.1.2 Economy Flats

3.1.2.1 The Tower

The Tower is situated at the mouth of the Economy River (Figure

6). For the last four years this flat has not been heavily dug commercially. Recruitment of a moderately dense year class in 1982 led to intense exploitation of both this flat and a similar one across the river channel, called the Miller Place (not surveyed).

The Tower was approximately 641 m wide. Inshore sediments were composed of a very black mud intermixed with some sand. At the bottom there were thick blue clays sometimes containing decomposing marsh grass which gave off unpleasant sulphur odours. Offshore areas had mud surfaces with higher proportions of sand below.

Of all the flats surveyed, the greatest density of clams, 152 per ft^2 (0.09 m^2), in a quadrat sampled, was dug on this flat. Overall the densities were very high. To the west of the area surveyed, clams were patchy and only found in high concentrations alongside tidal channels or in the lee of large boulders. To the east, there were larger proportions of gravel in the sediments and therefore lower densities of clams.

Offshore sample site 11, adjacent to the main river channel, was composed of very dense, stunted clams of variable size in mud-sand-gravel substrate. Clams were less dense, of a moderate size, and black in colour at inshore site 12, where blue clay substrates were covered with black mud.

3.1.2.2 Carrs Brook

When compared to all the other areas surveyed, this flat had the widest intertidal zone (Figure 6). Beginning at about 60 m from the high water mark, it stretched 1,154 m seawards. Sand and gravel high in the intertidal zone grade into mud-clays midshore and then sand-gravels offshore. A small salt marsh at the mouth of Carrs Brook contributes to the organic muds found on the flat.

The whole of the Carrs Brook flat was sampled, but only areas A, B, C, and D had any commercial quantities.

Densities of clams appeared to be relatively lower here than on other flats surveyed. Noticeably fewer clams were found in the central portion of the flat (area B), which was reportedly a result of intense digging in the spring. Heaviest commercial exploitation was therefore confined to inshore areas and to a lesser extent offshore. Clams found offshore were very large and white, while inshore they were moderately large and black in colour. On the average, clams were larger here than on the Bass River flats. No clams were found in areas of rippled sand such as that which occurred inshore.

There were two sites chosen for aging. Site 6 (area A, inshore) was very wet and muddy on the surface. Underneath there was some sand overlaying hard clay. Clams were moderately dense and medium to large in size. There were few small clams. Offshore site 7 (area D), located among numerous tidal channels, was very sandy. Clams exhibited a wide size range and were moderately dense.

3.1.3 Five Islands Flats

3.1.3.1 Harrington Beach

Harrington Beach, located at the mouth of the Harrington River, was the only Five Islands flat surveyed (Figure 7). Like Carrs Brook, it has historically been a good producer and is still heavily exploited today due to its proximity to Five Islands, where the majority of commercial clam diggers live. The portion of this flat inside the Harrington River Channel up to high water mark is closed to digging all year, due to bacterial pollution, and therefore was not surveyed. From the channel seaward, the flat was 436 m wide. Inshore sediments, imported from the adjacent salt marsh, are a black mud-sand-clay mixture. This eventually graduates into lighter

coloured mud-sands offshore. To the west, sandstone ledges become more common, while easterly there is a preponderance of gravel in the sediments. Few clams were found in the latter two offshore substrate types.

Juveniles from the previous year's settlement were observed inshore but in lower densities than on Sadies.

Offshore aging site 8 was chosen in a commercially worked area. Digging here was difficult because of the concentration of gravel and rock. Clams were moderately dense but patchy. Some animals appeared small and stunted, while others were larger and seemed to have normal growth rates. This phenomenon probably was related to substrate type as the large animals were concentrated in sandier spots.

Located close to the main Harrington River channel, inshore site 9 and surround had been recently dug by fishermen. Moderately dense clams of a wide size range were burrowed into sand-gravel bottom topped with black mud. Clams with shock marks, and others thick shelled and stunted, were observed.

3.1.3.2 Moose Island

This non-surveyed flat was visited at the beginning of August to determine the approximate acreage, densities, and sizes of clams, and to collect an aging sample. Recent commercial digging was apparent on this largely sandy clam flat. Small and medium size clams were found in moderate abundances interspersed with large numbers of dead shells. Clams were thin shelled, and did not seem to be stunted. Some variability of growth rates was evident. Midshore aging site 10 (Figure 7) was representative of these general characteristics. There were juveniles present but densities were less than at Sadies.

3.1.4 Advocate Harbour

We visited Advocate Harbour (not surveyed) at the end of August

(Figure 8). The trip from Lower Economy took approximately 1 1/2 hours. Over the last two years, fishermen from the Five Islands area have been travelling there to dig clams. This adds considerable time and expense to their fishing efforts and therefore is not a full time occurrence.

There are two areas of commercially exploitable clams. Access to one, Lubber Hole, is limited by distance and transportation problems, and therefore it is probably only lightly exploited. The major digging area is approached from the main town road. It stretches from Bog Brook around to Burke Brook and then seaward toward aging sample site 14. A much larger area than originally thought, it is likely also underexploited. On the whole, the area consists of very deep sand. Some muddy spots are found at the mouths of the brooks. The harbour is dissected by many channels. Clams at the aging site were moderately dense, mostly large (>50 mm), white in colour, and thin shelled. Nearby, evidence of digging acitivites were in abundance.

3.1.5 Remaining Non-surveyed Flats

The non-surveyed flats received only cursory inspections. Information on flat dimensions, and on densities and sizes of clams, was recorded. Some flats, such as Eddy's Beach and Sand Point (Figure 7), both in the Five Islands area, which had been historically good producers, became important again in 1982. Four years ago these flats had been heavily dug over. A strong year class of 1 3/4 - 2" (42-54 mm) clams in 1982 attracted numbers of clam diggers, so that harvesting became rather intense during the later part of the summer. Nearby Broderick's Beach, a very large flat, has also contributed significantly to the fishery in the past. Although difficult to work because it is very muddy, it will likely continue to be important in the future because of its size and proximity to Five Islands.

The Soleytown area at Lower Economy (Figure 6), also traditionally a good digging area, did not seem very productive in 1982, nor did it

appear to have any significant future potential.

The rest of the flats are either very small, low in productivity, or difficult to access because of position or distance, and therefore will only be marginal contributors to the commercial fishery in the future.

3.2 The Fishery

The commercial clam fishery is particularly important to the local economy. Digging extends from about mid-May to mid-October. The traditional harvesting implement is the clam hack (rake) and the harvest unit is the bushel (four 2-gallon buckets). Prior to 1982, clams were hauled into shore in bushel size onion bags (potato bags earlier), which were delivered to the clam buyers. Now five gallon white plastic buckets have been recommended for sanitary purposes by Fisheries and Oceans Canada officials. Boats are used to a lesser extent for bringing in the clam catch. Exceptions occur when large quantities are involved or a flat is isolated, such as at Moose Island. Most frequently diggers utilize a wheeled cart, called a "gig", which one man can operate. On very firm flats, accessible by road, motorized vehicles such as trucks and buggies are employed.

The recreational fishery is considered to be more valuable here than that on the Eastern Shore. Flats are large and numerous, easily accessible by car and on foot, and located near parks, camp grounds, cottages, and other tourist facilities. In the Five Islands area, flats utilized frequently by visitors to the area in 1982 included The Park, Sand Point, and Harrington Beach. Carrs Brook and Soleytown (Lower Economy) were popular in the Economy area.

Besides visitors from western parts of Canada and the United States, the area is heavily used by Nova Scotia residents, particularly from the Springhill and Truro areas. Fifteen percent of those interviewed during the survey were recreational fishermen.

3.3 Stock Assessment

A summary of sampling information for the three locations studied along the north shore of the Minas Basin is presented in Table 5. A total of 353.74 acres were covered by the survey. The greatest amount of acres surveyed, stations dug, and clams measured were on the Bass River flats. A further breakdown of this information on a per-area basis is found in Tables A3.1 - A3.3 in Appendix 3. Average number per ft^2 (0.09 m^2) and percentage size frequency distribution for all locations combined is given in Table 6. More detailed results by area, location and for the total, are found in Tables A3.4 - A3.9. For the whole north shore, the highest density (1.86/ft^2) and percentage (25%) of clams were found in the 1 1/2" (36-41 mm) size class (Figure 10). Forty-four percent of the population was concentrated between 1 1/2 - 2" (36-54 mm size classes). A total average density for all size classes of 7.36 clams/ft^2 was recorded (Table 6). This is less than densities observed in a similar survey conducted on the Eastern Shore in 1981, where 26.71 and 13.10 clams/ft^2 were documented for Chezzetcook and Sonora harbours, respectively (Witherspoon, 1982).

Bimodality of the size frequency distribution is a result of lower numbers of 3/4" (17-22 mm size class) clams (Figure 10). Abundances of <3/4" (0-16 mm size class) animals are likely underestimated due to sampling procedures; therefore this bimodality may have been stronger. A corresponding observation was made by Yeo (1978) for size frequencies of clams sampled along the south shore of the Minas Basin. Two explanations, or a possible combination of the two, are given. Success of spawning and settlement of young clams are known to vary from one year to the next (Brousseau, 1978). Therefore densities of clams in the <3/4" (0-16 mm) size class and subsequent ones may fluctuate depending on the quantities of animals produced at fertilization. Imposed on this natural fluctuation

Table 5. Acreage surveyed, number of areas, number of stations, and number of clams measured for the three locations along the north shore of the Minas Basin.

Location	Acreage*	Number of areas	Number of stations	Number of clams
Bass River Flats	199.58	5	598	4,871
Economy Flats	116.87	5	315	2,067
Five Islands Flats	37.29	1	120	2,727
Total	353.74	11	1033	9,665

* 1 acre = 43,560 $ft.^2$ = .41 hectare
1 m^2 = 10.76 $ft.^2$

Table 6. Average number/ft^2 (.09 m^2) and percentage size frequency distribution of clams sampled on the north shore of the Minas Basin for all locations combined.

Size Class (inches)	(mm)	Average number/ft^2	Percentage of total number (%)
<3/4	0-16	0.44	6
3/4	17-22	0.33	5
1	23-29	0.89	12
1 1/4	30-35	1.57	21
1 1/2	36-41	1.86	25
1 3/4	42-48	1.39	19
2	49-54	0.51	7
2 1/4	55-60	0.22	3
2 1/2	61-67	0.10	1
2 3/4	68-73	0.03	<1
≥ 3	≥74	0.02	<1
Total		7.36	100%

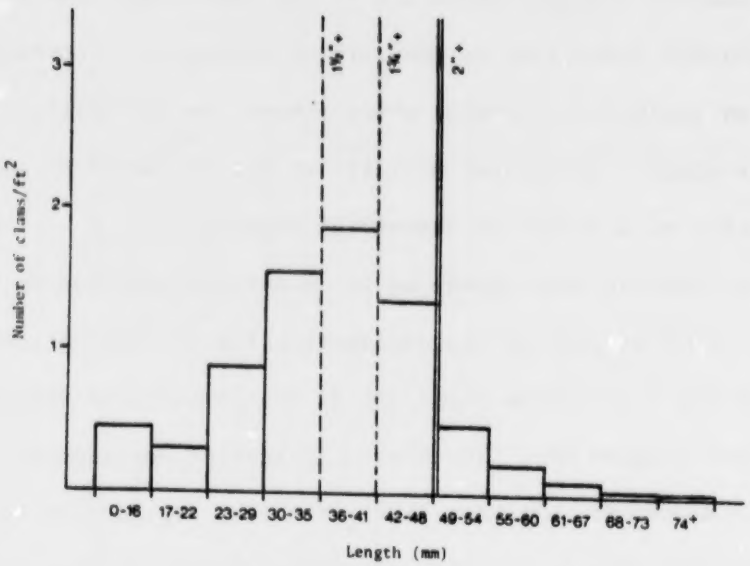

Figure 10. Size frequency distribution of the surveyed soft-shell clam population along the north shore of the Minas Basin, 1982.

Table 7. Summary of number/ft^2 (.09m^2) and percentage size frequency distribution for the three locations and all locations combined along the north shore of the Minas Basin.

Group	Bass River Flats Number/ft^2	%	Economy Flats Number/ft^2	%	Five Islands Flats Number/ft^2	%	All Locations Number/ft^2	%
Juveniles <3/4-1 1/4"	3.54	43	2.42	37	3.77	68	3.23	44
Prerecruits 1 1/2-1 3/4"	3.86	47	2.84	43	1.25	23	3.25	44
Markets ≥2"	0.75	9	1.29	20	0.49	9	0.88	12
Prerecruits 1 1/2"	2.33	29	1.44	22	0.61	11	1.86	25
Markets ≥1 3/4"	2.28	28	2.69	41	1.13	21	2.27	31
Total	8.15	100	6.55	100	5.51	100	7.36	100

are environmental changes, which act on the intertidal zone once the clams have established themselves in the surface sediments. Increased erosion or accretion of sediments, bringing about removal or smothering, can be lethal to juvenile clams. Additional mortalities may be caused by animal predators and indirectly as a result of commercial digging.

A dominant modal group of 10 mm animals observed by Yeo (1978) in 1975-76 could be part of the explanation for the strong year class observed at the 1 1/2" size class (36-41 mm) in our size frequency distribution for 1982 (Figure 10). The first explanation may account for this phenonenon to some extent, but more likely the real explanation is related to the accumulation of slow growing or stunted animals in this size class, which are found commonly on commercial flats along the north shore of the Minas Basin.

Such regular bimodality is not observed in other areas surveyed in the Maritimes (Robert, 1979; Robert and Smith, 1980; Robert, 1981; Witherspoon, 1982). Instead, single modal groups occur at a wide range of size classes. This suggests the possibility of specific and likely more severe environmental conditions which may be acting to concentrate animals in young and older size groups in the Minas Basin.

Comparisons of differences in densities between the three locations and between size groups were made (Table 7, Figure 11). The highest total number of 8.15 clams/ft^2 was observed on the Bass River flats, followed by Economy and Five Islands at 6.55 and 5.51 clams/ft^2, respectively.

Juvenile densities were found to be similar for all locations, with the Economy flats being slightly lower than the others. The combined juvenile density of 3.23 clams/ft^2 is considered relatively low, compared to other locations surveyed in the Maritimes. For the Chezzetcook and Sonora areas, juvenile densities were 19.75 and 6.97 clams/ft^2, respectively

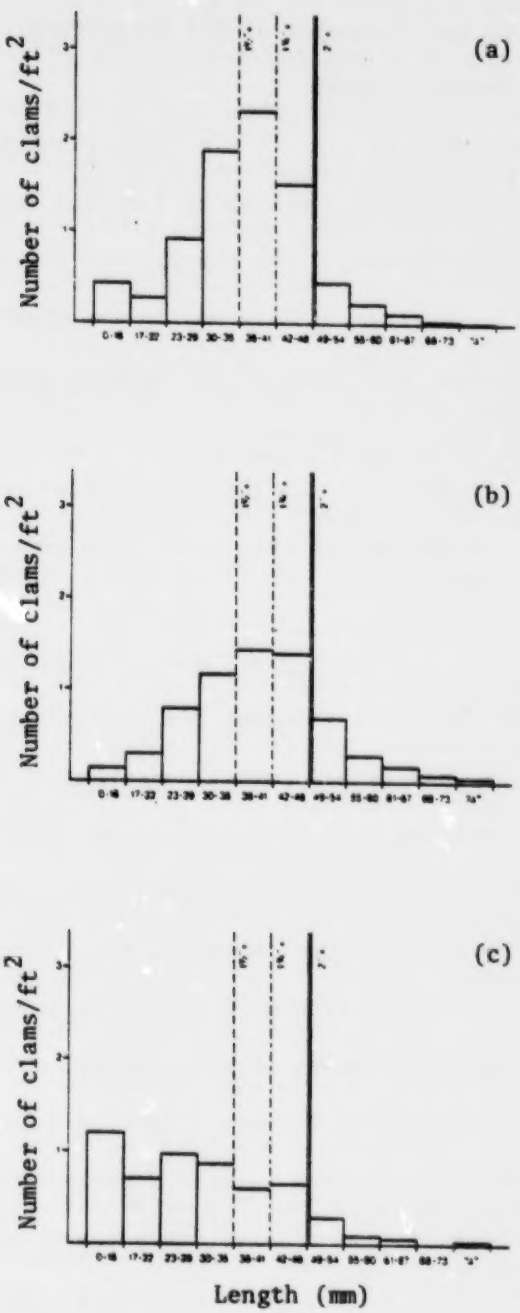

Figure 11. Size frequency distributions for all clams measured on (a) Bass River, (b) Economy, and (c) Five Islands flats.

(Witherspoon, 1982). In New Brunswick at Eel River Cove, 19.9 juveniles/ft^2 were recorded in 1978 (Robert, 1979).

Overall, prerecruit (1 1/2 - 1 3/4" size classes, 36-48 mm) density at 3.25 clams/ft^2 was comparable to values of 4.80 and 3.53 for Chezzetcook and Sonora harbours, respectively, along the Eastern Shore of Nova Scotia. Market size clams ($\geq$2" size class, $\geq$49-54 mm) in the Minas Basin were approximately 60-70% less abundant than those of the Eastern Shore. Density of 0.88 markets/ft^2 in the Minas Basin, compared to 2.16 and 2.58 for Chezzetcook and Sonora, is viewed as very low. An unfished population of clams at Eel River Cove, New Brunswick had market size clams with an average density of 20.2/ft^2.

Bass River flats had the highest densities of prerecruits for both Types 1 and 2. Markets were most abundant for both classification types on the Economy flats. Five Islands had lowest densities of prerecruits and markets of both types, but the most favourable number of juveniles at 3.77 clams/ft^2. Harrington Beach, the only flat surveyed at Five Islands, is an example of the result of overfishing. Harvests are likely to be poor here for 6 or 7 years until new recruits become available to diggers. The other locations have more promising numbers of prerecruits, which will slowly become available to the commercial fishery. This is true more so of the Bass River flats, where densities are largely a reflection of the accumulation of animals in prerecruit size classes, than the Economy flats.

A closer inspection of the distribution of clams on a per area basis can be accomplished by looking at Tables A3.7 - A3.9. At 10.19 clams/ft^2, Sadies B had the greatest density of clams overall. The most abundant number of juveniles (5.13/ft^2) was found on Sadies C. Sadies B had the highest densities of prerecruits at 5.43 and 3.38/ft^2 (Types 1 and 2, respectively). Market size clams were most highly concentrated in Carrs

Brook C (1.54/ft^2, Type 1) and at The Tower (3.26/ft^2, Type 2).

Bushel per acre production (Table 8) is the calculation of total quantities of prerecruits and market size clams, and is useful for comparisons in areas of commercially harvested stocks. For all locations combined, production of ≥1 1/2" size classes (≥36-41 mm) is moderately good at 86.62 bu/acre. Overall, prerecruits are more abundant than markets for Type 1, with the reverse being true for Type 2. Bushel per acre quantities of both prerecruit and market size clams for Bass River and Economy flats were 91.40 and 97.01, respectively. These quantities match other good to moderately abundant locations surveyed in New Brunswick (Robert and Smith, 1980) and Prince Edward Island (Robert, 1981). In contrast, the Five Islands flat productivity at 39.10 bu/acre is low. High production figures of 157.6 and 150.0 bu/acre were found for Chezzetcook Harbour and Sonora, respectively, in the 1981 survey along the Eastern Shore (Witherspoon, 1982). Bushel per acre production by individual flat is given in Appendix A3.10.

For those flats surveyed, the total estimated numbers of bushels available, by location and size groups, is summarized in Table 9. The approximate acreages and numbers of bushels for the remaining non-surveyed commercial flats is given in Tables 10 and A3.11. Along the entire north shore of the Basin, there was a combined potential of 1,115.94 acres of commercial clam flats with 67,113.9 bushels of market size clams (≥1 3/4" size classes, ≥42-48 mm) available for harvest at the time of the study (Table 11). If all this resource were taken in 1982, it would have had a landed sale value of over 1.3 million dollars ($20/bushel). According to finalized statistics for 1982, 39% of this potential resource has been landed (Table 12).

The 1982 survey was responsible for the in-depth study of only 32% of total commercial clam flats. The Five Islands flats have potentially

Table 8. Estimated bushels / acre of prerecruits and markets surveyed for individual locations and all locations combined on the north shore of the Minas Basin.

Group	Bass River Flats (bu/acre)	Economy Flats (bu/acre)	Five Island Flats (bu/acre)	All locations (bu/acre)
Prerecruits 1 1/2-1 3/4"	66.54	50.12	22.16	56.46
Markets ≥2"	24.86	46.89	16.94	30.16
Prerecruits 1 1/2"	36.25	22.40	9.49	28.94
Markets ≥ 1 3/4"	55.15	74.61	29.61	57.68
Total	91.40	97.01	39.10	86.62

Table 9. Estimated production (bushels)* of soft-shell clams in three locations surveyed along the north shore of the Minas Basin of the Bay of Fundy.

Group	Bass River Flats (bushels)	Economy Flats (bushels)	Five Islands Flats (bushels)	Total (bushels)
Prerecruits 1 1/2-1 3/4"	13,280.1	5,857.6	826.3	19,964.0
Markets ≥2"	4,961.5	5,480.0	631.7	11,073.2
Prerecruits 1 1/2"	7,234.8	2,617.9	353.9	10,206.6
Markets ≥1 3/4"	11,006.8	8,719.7	1,104.1	20,830.6
Total	18,241.6	11,337.6	1,458.0	31,037.2

*Production is based only on those flats which were surveyed by quadrat and transect line method.
One bushel = 60 lb. or 27 kg shell weight = $20 landed value in 1982.

Table 10. Estimated acreage and bushel production (≥ 1 3/4") of commercial clam producing locations not surveyed along the north shore of the Minas Basin of the Bay of Fundy in 1982.

Location	Acreage	Bushels
Bass River Flats	11.82	564.8
Economy Flats	208.16	9,625.6
Five Islands Flats	309.18	16,471.8
Advocate Harbour	233.04	19,621.1
Total	762.20	46,283.3

Table 11. Estimated total acreage and potential bushel production (≥1 3/4") of soft-shell clams of both surveyed and non-surveyed areas along the north shore of the Minas Basin, Bay of Fundy, 1982.

Location	Acreage	Percentage (%) of location surveyed	Bushels
East of Economy Pt.			
Bass River Flats	211.40	94	11,571.6
West of Economy Pt.			
Economy Flats	325.03	36	18,345.3
Five Islands Flats	346.47	11	17,575.9
Advocate Harbour	233.04	0	19,621.1
Total	904.54	17	55,542.3
Overall Total	1,115.94	32	67,113.9

Table 12. Landings[a] (metric tons[b] shell weight) and value (dollars) of soft shell clams in statistical District 43, on the Five Islands-Economy shore of the Minas Basin, Bay of Fundy from 1943-1982.

Year	Landings	Total Value	Value per Bushel[c]
1982	710	527,000	20
1981	621	455,182	20
1980	560	369,441	18
1979	499	237,859	13
1978	608	309,162	14
1977	370	177,113	13
1976	332	132,562	11
1975	406	179,415	12
1974	531	204,168	10
1973	510	169,094	9
1972	281	80,519	8
1971	214	36,295	5
1970	109	20,594	5
1969	161	24,477	4
1968	170	25,429	4
1967	162	24,054	4
1966	156	17,208	3
1965	132	14,587	3
1964	161	17,778	3
1963	139	15,362	3
1962	193	21,306	3
1961	221	21,911	3
1960	195	19,047	3
1959	295	32,571	3
1958	258	28,400	3
1957	285	34,000	3
1956	251	29,500	3
1955	203	20,200	3
1954	166	14,600	2
1953	206	18,500	2
1952	372	28,600	2
1951-1947[d]			
1946	916	33,000	1
1945	345	12,478	1
1944	128	4,242	1
1943	54	1,629	1

[a] Taken from Table 3 of Fisheries and Oceans statistical records, and the Dominion Bureau of Statistics.

[b] One Metric ton = 1,000 kg = 2,205 lbs.

[c] One bushel = 60 lbs = 27 kg = 4 peck buckets = 8 gal (U.S. dry measure).

[d] No landing statistics available.

the largest area of clam flats for exploitation, and Bass River the smallest.

3.4 Distribution

The survey was conducted so that information about densities of clams per height of the intertidal zone could be enumerated. Lack of time prevented the calculation of this sort of data. However, Little Bass River (Figure 5) and Carrs Brook (Figure 6) were broken up into areas which extended from inshore to offshore and can be studied as an alternative. Little Bass River B, the offshore area, had lower abundances of all size clams (Table A3.7). This appeared to be the case generally for most flats that were studied. Yeo's (1978) findings on the south shore of the Minas Basin supported these results, as he reported densities of $<1/ft^2$ in the lower part of the intertidal zone.

The opposite trend at Carrs Brook was observed (Table A3.8). This can be explained. The inshore parts of the flat are easily accessed. Offshore areas are much less available because of their great distance from shore and reduced digging times. As a result, areas A and B (Figure 6) have been heavily exploited while areas C and D have not.

Yeo (1978) explains reduced abundances of clams offshore as probably the result of "strong tidal currents and fluctuating sediment surface, which either cause erosional removal and/or poor spatfall patterns". Medcof (1945) proposed this view and further suggested that there may be increased predation by clam drills and flatfish in the lower part of the intertidal zone. Robert (1981) reports "silt and strong wave action limit clam distribution" offshore.

Lower survival of juveniles offshore is apparent at Little Bass River (Table A3.7); however, the opposite was true for Carrs Brook (Table A3.8). This again seems to be a phenomenon related to the heavy fishing inshore on the Carrs Brook flat, which likely produces greater mortalities

of juveniles than exhibited offshore where fishing pressure is much less. In contrast, Little Bass River represents the average situation because fishing effort is more equally distributed from inshore to offshore.

Another phenomenon which was generally noted during the survey and supported by data from Little Bass River (Table A3.7) and Carrs Brook (Table A3.8, Figure 12), was that of an increasing proportion of larger size clams seaward on intertidal clam flats. Lower densities of clams, greater distances, and shorter digging times make these areas less attractive to commercial diggers which results in lower harvesting pressure. Clams therefore grow larger as they are not removed as readily. Reduced densities, stronger tidal currents, and longer submergence times also enhance growth as more food is available for a longer period of time.

3.5 Density

Clam distribution on intertidal flats was found to be contagious - patches of very high densities of clams were found adjacent to areas with little or no clams. Using a variance to mean ratio index, Yeo (1978) statistically proved that clams were aggregated. He explained this occurrence by relating it to "the hydrodynamic sorting processes of larvae and juveniles in combination with better survival in locally sheltered areas", such as those described earlier under Section 3.1. Concentration of clams in the middle to upper parts of the intertidal zone is likely due to more suitable settlement conditions at the beginning of the ebb tide when tidal velocities are reduced. An additional explanation for this phenomenon has been proposed by Dickie (1955). He postulated that clam larvae are "gregarious and settle thickest in areas occupied by their own species".

Substrate type also has a great deal to do with successful establishment of juveniles. When clam larvae settle out of the water column, they require relatively large and stable particles to attach to with their

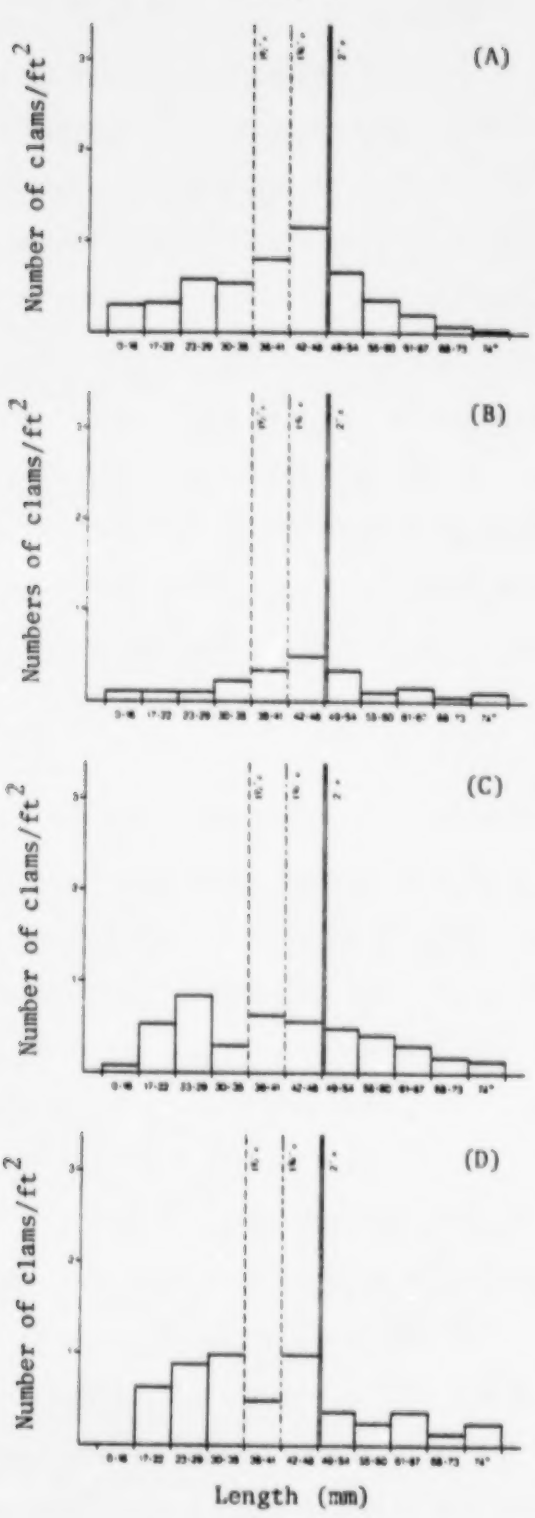

Figure 12. Size frequency distributions of clams, from inshore to offshore (areas A to D), for the Carrs Brook flat.

byssus threads. Soon after, they burrow into the substrate with their foot. Coarse grained sediments of Sadies C produced comparatively good sets of juvenile clams (Table A3.7). Long term survival is therefore dependent on the overall stability of the bottom sediments. Newcombe (1935) noted a scarcity of young set in soft muddy substrates or shifting ripple sands. As well, adult clams planted in the latter bottom type did not usually survive because their siphons filled with sand which they could not remove.

Another adult requirement which affects densities is that of adequate space. Shallow substrate depths and heavily gravelled sediments such as those described in Section 3.1 reduce total volume available for growth.

Yeo (1978) summarizes by saying "the major control over the establishment of Mya communities is dictated by an interaction between sediment stability and tidal currents". Further to this, long term survival of clams is enhanced in mixed substrate types and is likely a result of successful juvenile attachment, ease of burrowing to a moderate depth, space for growth, and bottom types not subject to large scale erosion or deposition for extended periods.

3.6 Growth

For most commercial clam areas of the Maritimes, market size regulations of 2" (51 mm) prohibit the taking of small clams. In the Minas Basin, where there are no length regulations, growth to this size is relatively slow. On the average 8 years are required. In contrast, clams on the south shore of the Gulf of St. Lawrence have the highest growth rates in the Atlantic Provinces, producing 50 mm clams on the average after five or six years (Robert, 1979, 1981). On the Eastern Shore, growth seems to be more variable and depends on local environmental conditions. At Chezzetcook and Sonora, 8 years are needed to reach harvest size (Witherspoon, 1982), and Medcof (1946) reported that at Musquodoboit and Clam harbours the age was lower.

In Passamaquoddy Bay at the head of the Bay of Fundy, it takes five or six years for clams to reach legal size (Newcombe, 1935). Outside of the Maritimes, in northern Massachusetts, Brousseau (1979) established that only 2 years were required to reach a 50 mm size.

Early workers in the Minas Basin observed a wide range of ages at 50 mm. Medcof (1949) documented 5-6 years at Lower Economy and 8 years at Five Islands. Newcombe (1935) reported an age of 5 years for Economy Point. This study also demonstrated the variability of ages (6 to 14 years) at 50 mm (Appendix 2).

Not only were growth rates variable from place to place but also from one year to the next. This phenomenon was apparent from aging the clams and was documented by Newcombe (1935).

Figure 13 and Table 3 show the divergent values for lengths at infinity (L_∞) and growth rates (k) calculated from the aging samples. The von Bertalanffy growth equation usually predicts that faster growing animals grow to a small size and slower growing animals grow to a large size. In the samples collected, both fast and moderately fast growing animals grew to small sizes. The moderately fast growing animals are indicative of the phenomenon of stunting, where an animal's growth is prematurely slowed down. Stunted clams usually are more rounded in shape, have thick shells, and do not grow much above a fixed size. In this study, those clams with L_∞ below 70 mm (2 3/4") were considered stunted. Half of the 14 aging samples collected could be classified as having this characteristic. Commercially, these animals are of concern because many of them could die of natural causes before reaching an acceptable size for harvesting. In fact, flats with high proportions of stunted clams were observed to have abundant numbers of dead clam shells, particularly Sadies. Medcof (1945) made similar mention about this matter during his early studies in the area.

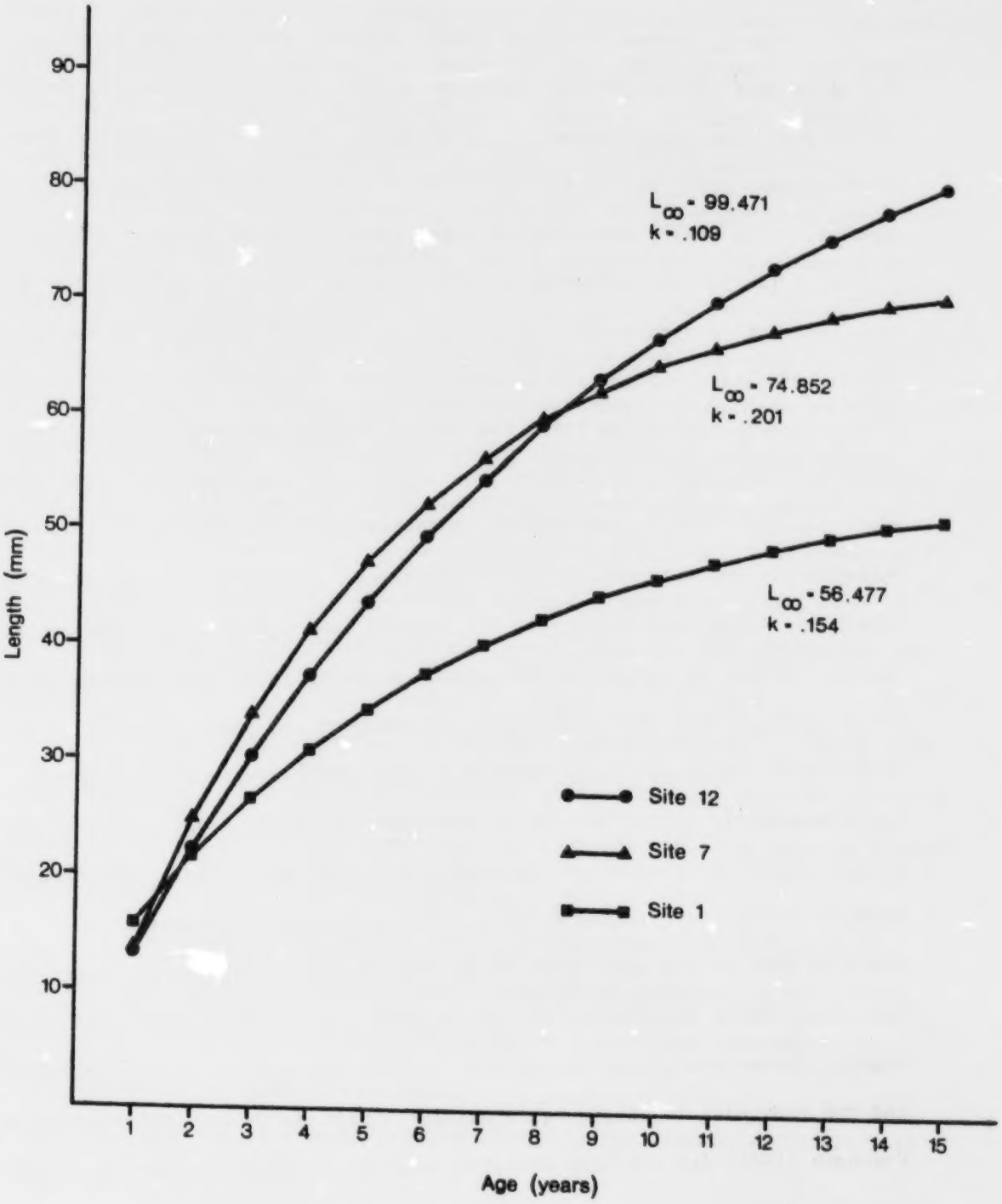

Figure 13. Length at age curves for slow (Site 12), medium-stunted (Site 1), and fast (Site 7) growing soft-shell clams on the north shore of the Minas Basin, 1982.

The L_∞ parameter of the growth equation predicts that no animals will grow past 100 mm (4") in the Minas Basin. In fact, during the survey the largest live animal measured was 86 mm (3 1/3"). On the Eastern Shore (Witherspoon, 1982) and on the south shore of the Gulf of St. Lawrence (Robert, 1979, 1981), some samples taken predicted growths above 100 mm (4").

The factors affecting growth rates and sizes of clams in the Minas Basin are both environmental and physical. Length of the growing season in the Bay of Fundy is short and extends from May to August inclusive (Newcombe, 1935). Growth during the first two months is greatest and is highly correlated with abundances of diatoms, the clam's most important food item. Newcombe reported that bottom diatoms, suspended into the water column from the intertidal zone, were the major type consumed. From September to December, growth is slowed down because of the reduced food supply. Low temperatures, January through to April, are postulated as being inhibitory growing conditions (ibid.). Yeo (1978) proposed that much of the food of benthic fauna in the Minas Basin was likely bottom diatoms and blue-green algae which bloom abundantly in the intertidal zone when the tide is out. He considered phytoplankton to be of minor importance as a food source for invertebrates because of its low relative density. Prouse (personal communication) reported that in the upper part of the Bay of Fundy, more particularly the Cumberland Basin adjacent to the Minas Basin, approximately one half of the organic carbon production is benthic diatoms, one quarter is phytoplankton, and the remainder is attributable mainly to salt marsh detrital production. Newcombe (1935) did not view detrital material as being an important food item for Mya.

Growth parameters k and L_∞ for all 14 aging samples were grouped by height in the intertidal zone. Clear cut trends were not apparent and no statistical analyses were carried out due to lack of time. Newcombe

(ibid.) sampled inshore and offshore sites in one location and found growth rates offshore to be greater than those inshore. This tendency held true in some of our locations but not in others (Table 3). One sample location, or even fourteen, may not be enough to draw any significant conclusions.

Stunted clams were mostly observed in the upper parts of the intertidal zones on those flats studied. Medcof (1945) stated that these clams normally lived close to the surface in dense populations and at high beach levels. Yeo (1978) observed that when substrates were less than 8-10 cm deep over bedrock and clams were present, they showed indication of stunting of shell growth. Robert (1981) found stunted clams in Prince Edward Island associated with hard beach substrates (rocks, pebbles, gravel) and shallow, soft sediments. The phenomenon of stunting seems to be associated with crowding, and with shallow and/or gravelly beach substrates, usually occurring higher in the intertidal zone where space and food for growth are limited.

Strong tidal currents can increase growth rates by providing more food per unit of filtering time (Newcombe, 1935). Digging over flats several times during the period of a year resulted in 5-10% reduction of clam growth (Medcof, 1945).

In summary, the factors which control growth in clams include quantity and timing of diatom blooms, temperature, position in the intertidal zone, proximity to salt marsh estuaries, substrate type and depth, clam densities and digging frequency.

Stunting is a major problem affecting the commercial industry in this region.

3.7 Reproduction

General gonad conditions were monitored from June through to September. Over the whole period no clear evidence of complete spawning

was noted in the areas where the collections were made. Clams that were inspected appeared to be well developed by the end of June. Ripe gonads with distinct spawning veins were still apparent in the last week of July. Some spawning and spent clams were observed the final week of August. By the middle of September most clams observed had partially spawned and were beginning to develop new gonadal tissue.

In contrast, clams on the Eastern Shore were totally spent by August (Witherspoon, 1982). Battle (1933) studied clam condition near St. Andrews, N.B. at the head of the Bay of Fundy from 1927-1928. She found a great number of mature specimens in June, with spawning reaching a peak about the middle of July. A secondary peak of mature individuals was observed in late July which was followed by a gradual shedding of germ cells until September. At this time gonads were laden with immature germ cells. She linked the initiation of spawning with spring tides, occurring during the middle of the day when temperatures of the flats were relatively high. Medcof (1941) described the same phenomenon in Prince Edward Island. He also reported spawning in the Digby area during June and July (Medcof, 1945). Robert (1981) found peak spawning throughout July in Prince Edward Island.

Spawning in the Minas Basin is likely a gradual process initiated by warmed intertidal zones of midday tides. Assuming a 5 week larval period (Brousseau, 1978), settlement of juveniles would occur from September through to October.

3.8 Catch and Effort Data

Catch per unit effort figures calculated from fishermen interview data are summarized in Tables 13 and 14. An observed seasonal decline from May to August in CPUE is verified by fishermen's comments of fewer commercial size clams to be found in the fall. Commercial (76 interviewed) and

Table 13. Monthly commercial catch per unit effort* (C.P.U.E.) for clam diggers interviewed on the north shore of the Minas Basin in 1982. Recreational catch per unit effort is also noted.

Month	Catch (buckets)	Effort (hours)	CPUE	Number of diggers interviewed
May	86.00	35.00	2.46	10
June	324.00	133.50	2.43	39
July	8.00	5.00	1.60	2
Aug.	195.75	86.25	2.27	25
Total Commercial	613.75	259.75	2.36	76
Total Recreational	26.00	32.50	0.80	13

*Catch is measured in 2-gallon buckets, effort in hours dug.

Table 14. Catch per unit effort (C.P.U.E.) for commercial diggers in two areas along the north shore of the Minas Basin, 1982.

Area	Catch (buckets)	Effort (hours)	CPUE	Number of diggers interviewed
Sadies	343.00	145.00	2.37	43
The Tower	189.25	83.75	2.26	24

Table 15. Soft-shell clam landings (metric tons shell weight) and value (dollars) for District 43 as compared to the totals for Nova Scotia 1980-82.

	District 43			Nova Scotia			% Nova Scotia	
Year	Landings	Value	Value/ Bushel	Landings	Value	Value/ Bushel	Landings	Value
1982	710	527,000	20	2,370	1,639,000	19	30	32
1981	621	455,182	20	2,136	1,504,014	19	29	30
1980	560	369,441	18	2,143	1,420,353	18	26	26

recreational (13 interviewed) diggers had CPUE's of 2.36 and 0.80 buckets per hour, respectively. Total recreational effort is thought to be relatively low compared to commercial effort because there are fewer numbers of fishermen, less hours dug, and lower CPUE's. Catch per unit effort statistics for Sadies and The Tower (Table 14) did not appear to differ significantly.

3.9 Landing Statistics

District 43 landings since 1943 are summarized in Table 12. Softshell clam landings are given in metric tons (MT) shell weight and include unspecified clams which are considered to by Mya. Value in dollars per bushel is rounded to the nearest dollar. Landing data is not available for the years 1947 to 1951. Figures for 1982 are complete, as of March 1983. Clams dug in Advocate Harbour, District 44, are reported in District 43. In the last three years, approximately 3% of the total landings reported from this area were shipped from Petpeswick Harbour on the Eastern Shore.

Overall, landing values are said to be underestimated because of the quantities of clams sold privately and dug by tourists. One fishery officer suggested a figure of 10% as that which might not be reported. It seems statistics records on this shore are better than in past years along the Eastern Shore (Witherspoon, 1982).

Early in the fishery, landings reflected abundance of marketable clams (Figure 2). More recently they reflect the increased product demand and therefore price per bushel. Landings to date are the highest since the early 1940's and are a result of greater fishing effort (larger numbers of fishermen) rather than improved CPUE figures, which have been declining since the 1940's. Additionally, greater harvests of small steamer clams (1 1/2 - 2" size classes, 36-54 mm) in the last 3 years have been increasing to offset lower catch success and to meet U.S. market demands. In previous years the catches were concentrated around 2" (51 mm). The popularity,

and therefore harvest, of steamer clams is likely to continue.

The value of this fishery in relation to the total Nova Scotian fishery has increased since the 1970's (Figure 1). In the last few years it has been worth approximately 30% (Table 15).

In 1981 the clam landings in District 43 represented 90% of the landed weight of all fish species in that District, and 67% of the value.

4. Discussion

The worth of the Minas Basin clam fishery is substantial in comparison to the total provincial clam fishery and has become more valuable in recent years. Present tough economic times and lack of management regulations threaten the long-term stability of the fishery.

Size regulation has become an important issue in the last few years, prompted by complaints about harvesting of small clams. Absence of size limit legislation has allowed a trend to fishing smaller and smaller clams. There is also evidence of lowered stock abundances as compared to earlier years of the fishery.

Compared to other Maritime clam stocks, present densities of clams indicate the industry is relatively healthy. However, a number of factors may operate on the fishery in the future to reduce abundances significantly.

Growth rates of clams are low and stunting is found in a high proportion of the population. This causes animals to accumulate in 1 1/2 - 2" size classes (36-54 mm). Increased fishing pressures will likely raise the proportion of clams harvested between these sizes. Bacterial problems may cause processors to do away with local shucking practices. This will further encourage the harvest of small clams. The major concern with depletion of stocks in this size range is related to the length at maturity.

Brousseau (1978) stated that clams are sexually mature at 1 1/2" (40 mm). Reproductive success and ultimately future stock abundance could be lowered by such practices. Establishment of juveniles in the Minas Basin is already known to be subject to great natural hazards.

Increased bacterial pollution and the potential development of a tidal power barrage may also threaten the economic viability of the fishery (Witherspoon, submitted for publication).

4.1 Management Recommendations

The Minas Basin clam flats are extensive and many places are unsuitable for commercial digging for various reasons. The likelihood of extinction of this species by overfishing is remote, but numbers could be reduced to levels which could not be economically harvested.

To assure the future financial success of this fishery, the following recommendations are made:

1) A relatively high proportion of clams that are found on commercial flats are stunted and may never reach a size of 2" (51 mm) before they die. Many of the other clams are slow growing and reach the same size after 6-9 years, thereafter increasing in length with relatively small yearly increments. Clams reproduce for the first time at approximately 40 mm. At present, harvesting begins at approximately 1 3/4" or 45 mm. A size limit of 50 mm would mean that there could not be a commercial fishery presently and one of 40 mm would eliminate a fishery for the future. Our optimal choice economically and biologically would be a mean size of 45 mm. This would allow animals one or two years of reproduction before being harvested. Stringent enforcement of this size limit would be necessary since the difference between 40 and 45 mm is very small.

2) Dickie and Medcof (1955, 1956) have discussed the inefficiency of harvesting practices which cause high mortality rates in clams. They found that on a flat dug over once, that only 60% of marketable clams are removed by diggers and that 50% of the clams left behind died because of smothering exposure, body damage, or gull predation. The more often a flat is dug over, the greater the mortalities. They suggested if flats were cropped once per year that the "eventual increase in CPUE would be enough to offset or even over-compensate for the loss of catch from the reduction in the total amount of digging". Other advantages of a larger standing stock besides increased yield and reduced labour were summarized. These included a larger spawning stock, promotion of better settlement of larvae because of their gregarious nature, increase in growth rates due to lowered disturbances, and maintenance of suitable physical conditions for settlement due to exclusion of competitors. Therefore, controls on the digging frequencies of flats would eventually lead to increases in yield.

3) Improvements in handling practices could also increase yield through reducing the amount of wastage. Clams may be broken during digging or in transportation to the processing plants. These clams are usually thrown away. A reduction in the proportion of spoiled clams could eventually bring greater returns to the fishermen.

4) During July and August of 1982, commercial harvest on some flats ceased because of high bacterial counts in clams. Unless proper sanitary methods are employed to treat waste produced along the Minas Basin shoreline, this will continue to be an increasing problem for the commercial fishery.

5) Recreational fishermen are not a threat to the commercial fishery, but their digging practices can adversely affect the catch rates of commercial fishermen. The sports digger has a habit of walking all over a flat and using shovels to take clams. Both practices obscure clam holes. Locating dense groups of large clams determines the commercial fisherman's ability to make a living. Many of these fishermen are in favour of licensing and limiting recreational diggers to flats that are not particularly important to the fishery. The fees could then be applied to enforcing these regulations.

Cooperation between commercial, recreational, and governmental individuals is a necessary prerequisite for effective management of the Minas Basin clam fishery.

5. Summary

1) Three hundred and fifty-four acres or one-third of the total commercially harvestable flats (1,116 acres) were surveyed during the summer of 1982.

2) Standing stocks (≥1 3/4" size classes, ≥42-48 mm) of 67,114 bushels, worth over 1.3 million dollars in 1982, were determined as being available to the commercial fishery.

3) Landings computed for 1982, using finalized data as of March 1983, indicate that only 39% of this potential has been harvested.

4) The greatest concentrations of clams occur between 36-41 mm (1 1/2" size class), otherwise known as prerecruits. Presently stock status appears to be healthy.

5) In recent years there has been low juvenile production which may affect future harvest, particularly if the trend for taking proportionally more steamer size clams continues.

6) Growth rates are low and stunting common along this shore.

7) Recreational effort is not considered a threat to the commercial fishery.

8) A size limit of 45 mm or 1 3/4" is recommended on both biological and economical grounds. Other management proposals are presented.

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APPENDIX 1

Form used for interviewing commercial and recreational clam fishermen.

Clam Fisherman Interview Form

Date: _____ Clam Flat: _____

Interviewer: _____ Time: _____

Total number of fishermen on flat: _____

Fisherman type: Recreational _____ Commercial _____

Number of hours digging: _____ Number of buckets*/day: ___

Total number of hours expected to dig: _____

Over what months do you intend to dig?: _____

How many days per month do you dig on average?: _____

Clam size range: _____ Average clam size: _____

Commercial Fishermen:

Historical information on Fishery (i.e. best year yet, etc.):

Present status of Fishery:

Major concerns of Fishery management:

What do you know and think about Fundy Tidal Power?

Recreational Fishermen:

How long do you intend to be in the area?: _____

How many days do you expect to dig?: _____

How many people in your party will be digging?: _____

How important is clam digging in relation to your overall holiday plans?

low _____ medium _____ high _____

Will you return to the area for clam digging this year _____

or in the future?: _____

* 1 bushel = 4 peck buckets (1 peck = 2 gallon bucket)

APPENDIX 2

Length at age for soft-shell clams collected along the north shore of the Minas Basin, 1982.

Table A2.1. Length (mm) at age (years) for soft-shell clams collected at Site 1 - Sadies A - Midshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	197	15.8	6	15.8
2	176	21.6	5	21.7
3	168	26.6	4	26.6
4	143	30.8	4	31.0
5	107	34.5	3	34.5
6	69	37.6	3	37.5
7	17	40.3	2	39.9
8	2	42.6	2	44.0
9	1	44.6	2	52.0
10	-	46.3	2	-
11	-	47.8	1	-
12	-	49.0	1	-
13	-	50.1	1	-
14	-	51.0	1	-
15	-	51.8	-	-

Table A2.2. Length (mm) at age (years) for soft-shell clams collected at Site 2 - Sadies B - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	195	14.1	7	14.2
2	176	21.2	6	21.2
3	156	27.0	5	26.9
4	130	31.9	4	32.0
5	82	35.9	3	36.0
6	40	39.3	3	40.0
7	9	42.1	2	40.6
8	3	44.4	-	43.3

Table A2.3. Length (mm) at age (years) for soft-shell clams collected at Site 3 - Sadies C - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	201	12.8	7	13.0
2	190	20.0	6	19.6
3	180	26.2	5	26.2
4	171	31.5	5	31.8
5	152	36.0	4	36.4
6	110	39.9	3	39.9
7	51	43.2	3	43.0
8	18	46.1	2	45.6
9	7	48.5	2	48.7
10	3	50.6	-	50.3

Table A2.4. Length (mm) at age (years) for soft-shell clams collected at Site 4 - Sadies A - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	210	13.0	9	12.9
2	198	21.8	8	22.0
3	182	29.4	7	29.6
4	148	36.0	6	36.2
5	105	41.8	5	41.7
6	19	46.9	4	44.8
7	2	51.2	4	50.0
8	1	55.1	3	57.0
9	1	58.4	3	63.0
10	1	61.3	3	64.0
11	1	63.8	2	67.0
12	1	66.0	2	69.0
13	1	67.9	-	70.0

Table A2.5. Length (mm) at age (years) for soft-shell clams collected at Site 5 - Sadies A - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	204	12.4	-	12.5
2	195	19.5	6	19.0
3	176	25.2	5	25.2
4	120	30.1	4	30.1
5	61	34.3	4	34.8
6	20	37.8	3	37.4
7	8	40.7	3	39.5
8	1	43.2	-	42.0

Table A2.6. Length (mm) at age (years) for soft-shell clams collected at Site 6 - Carrs Brook - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	192	13.7	10	14.0
2	185	24.1	9	23.4
3	156	33.0	8	32.9
4	98	40.6	7	41.0
5	56	47.1	6	47.5
6	20	52.7	5	53.8
7	7	57.6	4	55.3
8	4	61.7	4	62.8
9	2	65.2	3	64.0
10	1	68.2	3	65.0
11	1	70.8	-	80.0

Table A2.7. Length (mm) at age (years) for soft-shell clams collected at Site 7 - Carrs Brook - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	209	13.6	11	13.9
2	144	24.8	9	24.2
3	99	33.9	7	33.7
4	62	41.3	6	41.8
5	34	47.4	5	48.4
6	25	52.4	4	53.0
7	12	56.3	3	57.5
8	4	59.9	3	61.0
9	3	62.6	2	60.3
10	1	64.8	2	64.0
11	1	66.9	2	67.0
12	-	68.1	1	-
13	-	69.4	1	-
14	-	70.4	1	-
15	-	71.2	-	-

Table A2.8. Length (mm) at age (years) for soft-shell clams collected at Site 8 - Harrington Beach - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	219	15.6	9	15.7
2	172	24.7	8	24.2
3	116	32.5	7	32.8
4	65	39.1	6	39.4
5	30	44.9	5	44.5
6	10	49.6	4	49.5
7	4	53.7	4	50.8
8	2	57.2	-	58.0

Table A2.9. Length (mm) at age (years) for soft-shell clams collected at Site 9 - Harrington Beach - Inshore

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	202	15.8	9	15.9
2	153	25.0	-	22.6
3	94	30.4	6	30.4
4	64	36.3	5	36.9
5	44	41.0	4	41.3
6	30	44.9	3	44.7
7	16	47.9	3	47.1
8	6	50.4	2	50.0
9	1	52.3	-	54.0

Table A2.10. Length (mm) at age (years) for soft-shell clams collected at Site 10 - Moose Island - Midshore

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	160	14.2	10	14.1
2	150	23.7	8	23.8
3	142	31.6	7	31.7
4	43	38.1	5	37.4
5	11	43.5	4	43.6
6	4	47.9	4	50.0
7	3	51.6	3	52.7
8	1	54.6	-	51.0

Table A2.11. Length (mm) at age (years) for soft-shell clams collected at Site 11 - The Tower - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	224	14.5	9	14.5
2	194	23.1	7	23.1
3	164	30.1	6	30.7
4	53	35.8	5	34.7
5	19	40.4	4	39.4
6	19	44.1	3	43.7
7	14	47.1	2	48.3
8	4	49.5	-	51.0

Table A2.12. Length (mm) at age (years) for soft-shell clams collected at Site 12 - The Tower - Inshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	193	15.4	9	15.5
2	193	22.3	9	22.9
3	189	30.3	7	30.5
4	121	37.4	6	37.3
5	9	43.9	6	43.0
6	-	49.6	5	-
7	-	54.7	5	-
8	-	59.4	4	-
9	-	63.5	4	-
10	-	67.2	3	-
11	-	70.5	3	-
12	-	73.3	3	-
13	-	75.7	2	-
14	-	77.8	2	-
15	-	80.5	-	-

Table A2.13. Length (mm) at age (years) for soft-shell clams collected at Site 13 - Little Bass River - Midshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	276	10.3	-	10.5
2	275	17.6	-	17.2
3	265	24.3	6	24.2
4	198	30.4	6	30.6
5	100	35.9	5	36.2
6	28	40.9	5	40.1
7	7	45.4	4	44.4
8	3	49.5	-	46.3

Table A2.14. Length (mm) at age (years) for soft-shell clams collected at Site 14 - Advocate Harbour - Offshore.

Age	Number of rings measured	Fitted length	Growth increment $L_{t+1} - L_t$	Measured length
1	229	12.3	8	13.1
2	226	20.9	-	20.7
3	193	27.9	6	27.5
4	153	34.0	6	34.2
5	107	39.5	5	39.8
6	67	44.2	4	44.7
7	36	48.5	4	48.4
8	11	52.2	3	52.5
9	2	55.4	3	55.0
10	1	58.3	-	49.3

APPENDIX 3

Details of acreage and sampling stations, frequency distributions, number/ft^2 by size class, and bushels/acre production figures for all clam-producing areas along the north shore of the Minas Basin, 1982.

Table A3.1 Size and number of sampling stations for the clam producing areas on the Base River flats surveyed.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Sadies A	3,881,008	360,546	89.10	273
B	2,218,300	206,080	50.93	144
C	1,275,987	118,530	29.29	96
Subtotal Sadies	7,375,195	685,156	169.32	513
Little Base River A	1,143,598	106,240	26.25	74
B	174,512	16,212	4.01	11
Subtotal Little Base River	1,318,110	122,492	30.26	85
Total	8,693,305	807,608	199.58	598

Table A3.2 Size and number of sampling stations for the clam producing areas on the Economy flats surveyed.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Carrs Brook A	1,861,596	174,800	43.29	118
B	248,671	23,101	5.71	16
C	585,853	54,426	13.45	39
D	81,096	7,534	1.86	8
Subtotal Carrs Brook	2,797,216	259,861	64.22	183
The Tower	2,293,415	213,058	52.65	132
Total	5,090,631	472,919	116.87	315

Table A3.3 Size and number of sampling stations for the clam producing areas on the Five Islands flat.

Area	Size ft²	Size m²	Size acres	Number of sampling stations
Harrington Beach	1,624,313	150,899	37.29	120

Table A3.4 Size frequency distribution of the clams sampled by location along north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Clams found in samples: Base River Flats Number	%	Economy Flats Number	%	Five Islands Flats Number	%
0-16	<3/4	258	5	48	2	145	22
17-22	3/4	144	3	92	5	85	13
23-29	1	554	11	252	12	118	18
30-35	1 1/4	1143	23	371	18	104	16
36-41	1 1/2	1392	29	454	22	73	11
42-48	1 3/4	915	19	441	21	77	12
49-54	2	270	6	218	11	35	5
55-60	2 1/4	123	2	92	4	12	2
61-67	2 1/2	38	1	58	3	9	1
68-73	2 3/4	11	<1	23	1	0	0
>74	>3	3	<1	16	1	2	<1
Total		4871	100	2067	100	660	100

Table A3.5 Summary of the size frequency distribution for the north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Clams found in samples: Number	%
0-16	<3/4	451	6
17-22	3/4	341	5
23-29	1	924	12
30-35	1 1/4	1618	21
36-41	1 1/2	1919	25
42-48	1 3/4	1433	19
49-54	2	523	7
55-60	2 1/4	227	3
61-67	2 1/2	105	1
68-73	2 3/4	39	1
>74	>3	21	<1
Total		7,349	100

Table A3.6 Number ft^2 ($/100m^2$) in each size class for the three locations along the north shore of the Minas Basin.

Size Class (mm)	Size Class (inches)	Base River Flats number ft^2	Economy Flats number ft^2	Five Islands Flats number/ft^2
0-16	<3/4	0.43	0.15	1.21
17-22	3/4	0.27	0.29	0.71
23-29	1	0.93	0.49	0.98
30-35	1 1/4	1.91	1.18	0.87
36-41	1 1/2	2.33	1.44	0.61
42-48	1 3/4	1.53	1.40	0.64
49-54	2	0.45	0.49	0.29
55-60	2 1/4	0.21	0.20	0.10
61-67	2 1/2	0.06	0.18	0.08
68-73	2 3/4	0.02	0.08	0
≥ 74	≥3	0.01	0.05	0.02
Total		8.15	6.35	5.51

Table A3.7 Number ft^2 ($/100m^2$) in each size class by area, for Sadies and Little Base River flats.

Size Class (inches)	Size Class (mm)	Sadies A	Sadies B	Sadies C	Sadies Total	Little Base River A	Little Base River B	Little Base River Total
< 3/4	0-16	0.03	0.09	2.28	0.47	0.14	0.30	0.23
3/4	17-22	0.29	0.31	0.33	0.31	0.11	[illegible]	0.39
1	23-29	1.01	1.06	0.66	0.90	0.73	0.82	0.74
1 1/4	30-35	1.44	2.09	1.80	1.65	2.30	1.99	2.28
1 1/2	36-41	1.47	3.38	2.69	2.23	3.16	1.39	2.89
1 3/4	42-48	1.22	2.05	1.33	1.47	2.01	0.91	1.87
2	49-54	0.50	0.48	0.26	0.45	0.49	0.27	0.46
2 1/4	55-60	0.23	0.17	0.26	0.22	0.08	0.36	0.12
2 1/2	61-67	0.10	0.03	0.06	0.07	0.01	0.09	0.02
2 3/4	68-73	0.03	0.02	0	0.02	0	0	0
≥3	≥74	<0.01	0	0.02	0.01	0	0	0
Juveniles		2.77	4.96	5.15	5.59	5.46	2.27	5.51
< 3/4 - 1 1/4"		83.5%	80.4%	52.0%	64.5%	57.7%	47.5%	56.0%
Prerecruits		2.69	5.45	4.02	5.70	5.17	2.39	4.76
1 1/2 - 1 3/4"		42.6%	53.5%	41.2%	45.9	56.0%	50.1%	51.7%
Markets		0.90	0.70	0.60	0.77	0.58	0.72	0.64
≥2"		13.6%	6.9%	6.2%	9.6	6.3%	14.8%	6.9
Prerecruits		1.47	3.38	2.69	2.23	3.16	1.09	2.69
1 1/2"		23.3%	33.2%	27.6%	27.7%	34.2%	21.9%	33.2%
Markets		2.08	2.75	1.93	2.24	2.59	1.63	2.47
≥1 3/4"		32.9%	27.0%	19.8%	27.8%	28.1%	32.7%	28.4%
Total		6.32	10.19	9.73	8.05	9.23	4.99	8.72
		100%	100%	100%	100%	100%	100%	100%

Table 13.8 Number/ft^2 (.09m^2) in each size class by area, for the Economy flats.

Size Class (inches)	(mm)	Carrs Brook A	B	C	D	Total	The Tower
<3/4	0-16	0.30	0.11	0.08	0	0.22	0.06
3/4	17-22	0.32	0.11	0.54	0.65	0.36	0.20
1	23-29	0.56	0.11	0.65	0.88	0.61	1.07
1 1/4	30-35	0.55	0.22	0.51	1.30	0.49	2.14
1 1/2	36-41	0.81	0.33	0.62	0.50	0.66	2.53
1 3/4	42-48	1.10	0.50	0.56	1.00	0.96	2.01
2	49-54	0.6"	0.33	0.49	0.38	0.50	0.64
2 1/4	55-60	0.36	0.11	0.41	0.25	0.34	0.22
2 1/2	61-67	0.20	0.1"	0.31	0.38	0.23	0.12
2 3/4	68-73	0.08	0.0b	0.18	0.13	0.10	0.05
≥3	≥"4	0.03	0.11	0.15	0.25	0.08	0.02
Juveniles		1.78	0.55	1.78	2.51	1.66	5.4"
<3/4 - 1 1/4"		54.0%	25.5%	39.6%	46.5%	36.2%	3".3%
Prerecruits		1.9"	0.83	1.14	1.50	1.62	8.34
1 1/2 - 1 3/8"		58.9	38.4.	2b.2%	2".8%	34.9%	49.4%
Markets		1.34	0.78	1.54	1.38	1.34	1.25
≥2"		26.8%	3b.1%	34.2%	25.7%	28.9%	13.2%
Prerecruits		0.81	0.33	0.62	0.50	0.66	2.53
1 1/2"		16.9	15.3%	13.8%	9.2%	14.2%	2".3%
Markets		2.50	1.28	2.10	2.39	2.30	5.2b
≥1 3/4"		49.4%	59.2%	46.7%	44.3%	49.6%	26.2%
Total		5.06	2.16	4.50	5.40	4.64	9.7b
		100%	100%	100%	100%	100%	100%

Table 13.9 Number/ft^2 (.09m^2) in each size class for the Five Islands flat.

Size Class (inches)	(mm)	Harrington Beach
<3/4	0-1e	1.21
3/4	17-22	0.71
1	23-29	0.98
1 1/4	30-35	0.87
1 1/2	36-41	0.61
1 3/4	42-48	0.64
2	49-54	0.29
2 1/4	55-60	0.10
2 1/2	61-6"	0.08
2 3/4	68-"3	0
≥3	≥"4	0.02
Juveniles		5."""
<3'8 - 1 1/4"		68.4%
Prerecruits		1.25
1 1/2 - 1 3/8"		22.7%
Markets		0.49
≥2"		8.9
Prerecruits		0.61
1 1/2"		11.1%
Markets		1.13
≥1 3/4"4		20.5%
Total		5.51
		100"

Table A5.10 Estimated bushels/acre of prerecruits and markets for areas within locations on the north shore of the Minas Basin.

Locations and areas	Bushels/acre				
	Prerecruits 1 1/2-1 3/4"	Markets ≥2"	Prerecruits 1 1/2"	Markets ≥1 3/4"	Total
Bass River Flats					
Sadies A	47.03	28.70	22.87	52.96	75.73
B	93.17	22.01	52.58	62.60	115.18
C	68.18	18.56	41.85	44.89	86.74
Total Sadies	63.80	25.70	34.69	54.81	89.50
Little Bass River A	88.96	16.76	49.16	56.56	105.72
B	34.98	24.90	16.96	42.92	59.88
Total Little Bass River	81.99	17.90	44.96	54.95	99.89
Total Bass River Flats	66.54	24.86	36.25	55.15	91.40
Economy Flats					
Carrs Brook A	55.60	45.31	12.60	71.31	83.91
B	15.05	33.38	5.13	43.28	48.41
C	20.74	46.05	9.86	57.12	66.97
D	27.58	65.12	7.78	84.92	92.70
Total Carrs Brook	29.25	51.94	10.27	70.95	81.22
The Tower	79.16	41.54	39.36	81.14	120.50
Total Economy Flats	50.12	46.87	22.40	74.01	97.01
Five Islands Flat					
Harrington Beach	22.16	16.94	9.89	29.81	39.10
Total Five Islands Flat	22.16	16.94	9.89	29.81	39.10
Survey Total	56.26	30.16	28.94	57.68	86.62

Table A5.11 Estimated acreage, bushels/acre (≥1 3/4"), and bushel production of commercial clam producing flats not surveyed along the north shore of the Minas Basin, 1982.*

Locations and areas	Acreage	Bushels/ acre	Bushels
Bass River Flats			
Five Houses	7.04	42.92	302.2
Saints Rest	4.78	54.93	262.6
Total Bass River Flats	11.82		564.8
Economy Flats			
The Miller Place	18.09	81.14	1,467.8
Soleytown - Lower Economy	190.07	42.92	8,157.8
Total Economy Flats	208.16		9,625.6
Five Islands Flats			
Old Wife	8.25	42.92	354.1
Sand Point	55.29	81.14	2,863.4
Eddys Beach	51.06	81.14	4,145.0
Brodericks Beach	139.53	42.92	5,988.6
Moose Island	39.52	29.61	1,164.5
Blue Sac Beach	35.75	54.81	1,958.4
Total Five Islands Flats	309.19		16,471.9
Advocate Harbour Flats			
Lubbers Hole Flat	21.62	77.12	1,667.5
Advocate Flat	211.42	84.92	17,953.8
Total Advocate Harbour	233.04		19,621.1
Total Non-Surveyed Areas	762.20		46,283.3

*See Section 2.2.2.1 for estimation procedures.